NRA
Thames Region

KENNET AND COLN RIVER LEVELS STUDY

Final Report

VOLUME ONE - RIVER KENNET

K1064/070/0/004

WS/Atkins

May 1992

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FINAL REPORT

VOLUME ONE - RIVER KENNET

CLIENT: National Rivers Authority - Thames Region

CONSULTANT: WS Atkins Consultants Ltd.

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EXECUTIVE SUMMARY

This document is Volume One of a two volume Final Report on the Kennet and Coln River Levels Study and considers the Upper Kennet catchment above Knighton gauging station. The Study was commissioned largely as a result of public concern that the character of the river had changed over the last 30 years. The fundamental concern was with reduced river levels and the general view was that reductions were caused, in great part, by groundwater abstraction for public supply outside the Kennet catchment.

The Study was divided into two stages and an Interim Report on the Stage One Study was issued in December 1991. This Report updates the findings of the Stage One Study and presents the findings for both Stage One and Stage Two.

Stage One of the Study considered how the four main measures of the character of the catchment viz:

- Groundwater levels
- Surface flow, water level and the upper limit of flow
- Water quality
- Flora and fauna

have changed with time. Three separate approaches were undertaken for each factor as below:

- Public perception, from interviews with local concerned individuals and groups.
- Historical perspective, from research into historical maps and records.
- Factual analysis, from the available data.

The main findings of the Stage One Study were :

- The river has dried to Marlborough about once every 10 years during this century. There is evidence that this also occurred during earlier years.
- The catchment above Marlborough was reported as having deteriorated substantially over the 50 year period up to the 1940's. Many of the concerns expressed at that time are parallelled in current concerns.
- There is no factual evidence for a change in the surface flow rate to Marlborough. There appears to be a reduction in flow

at Knighton by approximately 10 Ml/d dating from the mid 1970's.

- Groundwater levels and water quality have varied significantly over the period of record.

- There has been a widespread loss of submerged weed throughout the catchment and replacement with both emergent vegetation and blanket weed.

Stage Two of the Study considered the possible causes of the changes identified in Stage One. The main findings were:

- The upper reaches above Marlborough were intensively managed up until the 1930's. The common purpose of this management was the control and retention of water, whether for water meadows, mill operation or fish rearing. The levels in the river were increased artificially over much of the year. As these management practices were phased out over the first few decades of this Century, the appearance of the river will have changed significantly over much of the year. It is considered that the changes resulting from reduced river management were one of the main causes of the public concern expressed during the 1940's.

- The current drought period is of a length (42 months to date) which has a particularly severe impact on the chalk. This drought is one of the most severe over the 70 year data period with regard to its impact on the chalk aquifer.

- The current condition of the river above Marlborough is considered to be largely natural and only affected marginally by groundwater abstraction. The reach is unusual in that it dries naturally over its total length (10km) in response to drought events of approximately 10 year return period. Dredging of the upstream section has also changed the character of specific lengths of this reach.

- In general, the variations in groundwater level and water quality appear to have been in response to natural fluctuations in effective rainfall. There is no clear evidence that groundwater levels over the catchment have been affected by groundwater abstraction.

- The river below Marlborough is affected primarily by the drought. However, a significant subsidiary effect is groundwater abstraction. The nett impact of abstraction, i.e. subtracting effluent return contributes an estimated one fifth of the total flow reduction.

- The major cause of the concerns in the reach below Marlborough is reduced flow velocity. This is a function of both flow rate and cross sectional area. In many reaches over-dredging in the 1950's has contributed substantially to the reduction in natural flow velocity.

- Reduced flow velocity has led to the loss of submerged weed and replacement with emergent and encroaching vegetation, blanket weed and algae. Siltation and decayed leaf matter has increased and is less likely to be removed during Winter flood flows.

- The loss of weed leads to significant reductions (typically a halving) in river level. The food chain and shelter is also lost for the wild trout population and fishing interests are adversely affected. Similar changes in the character of weed growth are reported from many other chalk streams in the south east of England.

At the end of the Report various remedial measures and further works are suggested.

KENNET AND COLN RIVER LEVELS STUDY
FINAL REPORT
VOLUME ONE - RIVER KENNET

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STAGE TWO - POTENTIAL FACTORS IN CAUSING CHANGE

GENERAL

1. INTRODUCTION

In October 1991 the National Rivers Authority - Thames Region appointed WS Atkins Consultants Ltd to undertake a study of the Upper Kennet and Coln Rivers. The study was divided into 2 stages and in December 1991 we produced an interim report (K1064/070/O/001) presenting the findings of the Stage One study with respect to both rivers. In February 1992 we produced Draft Final Reports in two volumes for the Kennet (Volume One - K1064/070/O/003) and Coln (Volume Two - K1064/070/O/004).

This volume of the Final Report (Volume One) presents the findings from both Stage One and Stage Two of the Study for the River Kennet revised and updated following a review of the Draft Report. Volume Two presents the findings from Stages One and Two for the River Coln.

Both the Kennet and Coln rivers have been the subject of considerable public concern as to their condition and, in particular, the river levels over the past few years. In both cases the fundamental cause of change in river condition was considered by the public to be groundwater abstraction and export from the catchment. The initial data analysis by NRA-Thames did not substantiate this viewpoint but the public debate continued. It was decided therefore to commission this two stage study examining, in Stage One, the changes which the catchment has undergone over the historical record and, in Stage Two, the contributory causes of the changes identified.

The Report on Stage One is divided into four sections (Section 4 to 7), assessing the following parameters for evidence of change in catchment characteristics:

- Groundwater Levels
- Surface Water Flow, including river levels and upper limits of flow
- Water Quality
- Flora and Fauna

Each of these factors are considered with respect to:

- Historical Perspective - references to catchment characteristics from historical documents.

- Public Perception - contributions received both in writing and during meetings with local inhabitants and interest groups.

* Factual Data - analyses of data held by the NRA or collected from third parties during the study.

The changes are identified and summarised at the end of each section and initial conclusions, specific to the factor, are made.

The Report on Stage Two is divided into 5 sections (Section 9 to 13) considering each of the potential causes of catchment change, as below:

- ° Meteorology
- ° Abstraction
- ° Discharge
- ° River Management
- ° Land Management

The history of the catchment with respect to each of these features is considered and the changes with respect to each of them are analysed. The findings are summarised in Section 14, wherein the relative contribution of each factor to the changes in river environment identified in Stage One are considered.

An A3 plan of the catchment is included in most sections showing the location of each of the specific sites noted. A letter coding is used in the text, following the site name (e.g. Marlborough gauging station (A)), and the encircled letter is used to identify the location on the plan.

ACKNOWLEDGEMENT

This study, by its nature, has been very reliant on information from members of the public and data from NRA staff. We are very grateful to all contributors and would like to thank all those who have helped in the production of this Report. Particular thanks are given to NRA staff, Action for the River Kennet (ARK), Kennet Valley Fisheries Association (KVFA) and the Salmon and Trout Association (STA) for their help, advice and endeavours.

2. BACKGROUND TO THE STUDY

2.1 Study Area

The Upper Kennet is defined as the catchment upstream of the Knighton gauging station. The catchment is in the central southern England county of Wiltshire and on the south western boundary of the NRA - Thames Region (Figure 2.1). The catchment is predominantly rural in nature and is part of the North Wessex Chalk Downs (also known as the Berkshire Downs) which extend beyond the catchment boundaries to east and west. The area is considered to be one of the parts of England first settled by man and is best known for its many relics of the Neolithic Period, including Avebury stone circle and Silbury Hill. The northern catchment boundary is defined by the chalk ridgeway, an ancient pathway and one of the country's National Trails.

The River Kennet flows southwards and eastwards across the Lower, Middle and Upper Chalk strata as shown on Figure 2.2. The river is joined by the Og at Marlborough and the Aldbourne at Ramsbury and the surface catchment covers a total area of 295 square kilometres. The upper parts of the Kennet (known as the Winterbourne) the Aldbourne and much of the River Og catchments are recognised as being ephemeral in nature, that is surface flow is not present throughout the year. 'Bourne' itself is an old term for "intermittent stream". One of the main issues of the study is whether the downstream limit and period of bourne-type flow has changed in recent years.

The upland areas of the catchment are developed mainly for arable farming and pasture land is mostly restricted to the valley floor. Urban development is confined largely to Marlborough although there are a number of smaller towns and villages located along the river valleys.

2.2 History of Public Concern

This section provides a brief overview of the history of public concern as to the river character. Detailed descriptions of public concerns and perceptions can be found in each of the specific sections.

There are a number of earlier descriptions as to the nature of the catchment but the first reference to public concern as to changes in the river character is from an old river keeper, remembering his landlord's worries in the 1930's that the new borehole at Shepherds Shore would reduce flows in the river.

Colonel GK Maurice of Lockeridge published a detailed and interesting account of the changes he witnessed in the Upper Kennet above Marlborough between his boyhood in the 1890's and the 1940's. The article was entitled 'Passing of a River - an Obituary' (Maurice, 1947) and linked the observed decline in river condition directly to public supply groundwater abstraction. This concern was also expressed forcibly during the Public Enquiry of 1948 examining the proposals for increased abstraction at Clatford Pumping Station.

In recent years, the degree of public concern about river levels, and associated changes in flora and fauna, has grown steadily. A public meeting was held in February 1989 to discuss the issue and following a further meeting in February 1991 a river protection society, Action for the River Kennet (ARK), was formed by the local community. The local inhabitants are, in general, of the opinion that the major factor governing reductions in river level is public supply groundwater abstraction.

LOCATION PLAN

FIGURE 2.1

UPPER RIVER KENNET CATCHMENT
CATCHMENT GEOLOGY

FIGURE 2.2

3. CATCHMENT GEOLOGY AND HYDROGEOLOGY

The Kennet valley is formed by a shallow syncline in the chalk, the axis of which dips gently to the east. The surface catchment boundary to the north, south and west is marked by a steep chalk scarp slope. The catchment geology is illustrated on Figure 3.1.

There is, in general, very little surface runoff in the catchment and the effective rainfall (considered as the residual rainfall following evaporation and transpiration) is virtually all recharged to the chalk aquifer. The upland area has a cover of clay drift (not shown on Figure 3.1) and recharge is believed to be concentrated along the margins of this clay cover material. The basal parts of the Lower Chalk, with a higher clay content and lower transmissivity, have a higher runoff and this is a significant proportion of the ephemeral flows in the Kennet Winterbourne upstream of Berwick Basset (A).

To the west of the River Kennet there is a large expanse of upland Lower Chalk plain extending to the scarp. In the western part of this plain, groundwater moves westwards to outflow along spring lines on the scarp slope and outside the surface water catchment. For this reason the groundwater catchment is significantly smaller than the surface water catchment. The dividing line between eastward and westward flow is the groundwater catchment divide, the line of which is discussed further in Section 4.

Chalk transmits and yields groundwater mainly through fissure flow. Fissure development is controlled as follows:

- vertical and sub-vertical fissuring is structural and associated with faulting. These planes of weakness are often also reflected in the alignment of valleys.

- horizontal fissuring and void development is often related to changes in the nature of the chalk. A major zone of fissuring is typically associated with the hard, nodular Chalk Rock which divides the Upper from the Middle Chalk and the Melbourne Rock at the division between the Middle and Lower Chalk.

- chalk is soluble in undersaturated waters and the through flow of groundwater tends to further develop existing fissuring.

- The fracture development in the Upper and Middle chalk is typically similar. The clay content in the Lower Chalk increases from top to base and this has tended to reduce fracture development.

As a consequence of these factors, a large proportion of the total groundwater flow within the catchment is concentrated along the catchment valleys. Individual or groups of springs, associated with major fissures are typically the source of a large proportion of the baseflow to certain reaches of the river, with little contribution from the intervening reach. Major springs are often at or near the junction of the Middle and Upper Chalk.

The influence of these hydrogeological features on the surface flow characteristics of the Kennet are considered further in Section 5.

UPPER RIVER KENNET CATCHMENT
CATCHMENT HYDROLOGY & HYDROGEOLOGY

FIGURE 3.1

STAGE ONE -
CHANGES IN CATCHMENT CHARACTERISTICS

4. GROUNDWATER LEVELS

4.1 General

In addition to the major public supply sources the chalk aquifer has been used extensively for small scale and domestic water supply and as a consequence there are a large number of wells and boreholes in the catchment. The water levels in many of these are measured regularly by NRA - Thames as part of their groundwater monitoring network and these data are considered in Section 4.4.

Groundwater levels at individual monitoring points vary typically from 2 to 15 metres over a year from a maximum level near the end of the recharge period (typically in March or April) to a minimum level at the end of summer. As the great majority of surface flow is derived from groundwater baseflow, river hydrographs mirror this seasonal pattern. A typical groundwater hydrograph, from Rockley Well (A) is illustrated in Figure 4.2 and also shows the minimum, mean and maximum levels over the last 20 years.

Domestic water wells were generally dug by hand at the time that the house was constructed. Due to difficulties in construction below the water table these were typically only extended to 1 or 2 metres below the water level. The well digger would return to the well to deepen it as necessary during the following low water level period and each subsequent period that the well was dry for a significant time span. It was noted during conversation with Mr Philpott of Lockeridge that a local well digger was operating in the Lockeridge area in the 1920's and would deepen a well if the level was within ½ metre or so of the base. As discussed in Section 4.3 below, Whatleys of Pewsey are still operating a similar service. It follows therefore that the depth of a well is generally a good indication of the lowest water level sustained at that location over the entire period during which the well was the sole source of domestic water.

This useful, but not infallible, indicator has been of use in the following parts of this section.

4.2 Historical Perspective

Groundwater levels have been recorded at irregular intervals from a number of supply boreholes since the turn of the century (HMSO, 1976). These data do not show any clear trend over this period however.

Documents made available by the local river protection society 'Action for the River Kennet' (ARK) include correspondence relating to a Public Enquiry for a borehole in Avebury in the 1940s. The borehole was proposed through the 1945 Water Act and one of the fundamental justifications for the public supply was that private domestic wells in the Upper Kennet area were '... occasionally becoming dry'. It was not made clear however whether this phenomenon was recent in origin. The Enquiry eventually resulted in an increased abstraction from the existing borehole at Clatford.

Professor Hawkins of Reading University published a Report on the 'Hydrogeological Features of the London Basin West of Marlborough' in 1948. Professor Hawkins expressed concern that groundwater levels in the chalk aquifer in this area may be gradually being reduced as part of a natural drainage process to the spring outflows around the scarp face and that this process was being accelerated by groundwater abstraction.

This concern of Professor Hawkins' betrays a fundamental misunderstanding of the groundwater flow regime and may explain, at least in part, the concerns of the general public as to the impact of abstraction on groundwater levels. A belief in the cumulative impart of groundwater abstraction has also been noted from a number of discussions with members of the public.

It is a fact that a significant proportion of recharge to the surface catchment outflows outside the catchment to springs at the base of the chalk scarp face to the north, south and west. The mean outflow was estimated in a recent NRA Report as 47 Ml/d or 16 per cent of the total surface catchment resources (Ingles 1990). It should be stressed however that this is a relatively common, natural and sustainable catchment flow characteristic and there is no justification for considering that the Kennet catchment is being reduced by natural drainage.

Abstraction and export of groundwater from the catchment will reduce both groundwater levels and surface flows below the natural condition. Ongoing abstraction does not have a cumulative effect however, until and unless abstraction becomes greater than recharge, and this is far from being the case in this catchment. Both groundwater levels and surface flows stabilise at a lower level, dependent on the magnitude of the abstraction.

4.3 *Public Perception*

Dry Wells

Last year (1991) Action for the River Kennet (ARK) prepared two reports from their studies on the Upper Kennet detailing interviews with local inhabitants as to historical changes in the river. There are a number of references to dry wells in these documents, as below:

- The well at Windmill House in Winterbourne Monkton (B) was reported to have dried in 1976. Subsequently a water supply was available until late 1989 when supplies dried for two months and again in October 1990 when a supply did not return until early March 1991, a total of 5½ months.

- A well at East Kennet, owned by the same family since the 1940s, dried up for the first time to their knowledge in 1985-6 and has done so on several occasions since.

In November 1991 we visited Whatleys Drillers of Pewsey, an old established firm who have installed and deepened a large number of wells in the Kennet catchment. They reported that, in general, requests for well-deepening followed a drought period and their records revealed well-deepening works following the drought years of 1921, 1934 and 1946. In recent years clients have requested that wells are replaced by boreholes, which are not as restricted by depth considerations, and they have installed a number of these in the recent past.

Swan Cottage in Avebury (C) was built in the early 1700's and is believed to have had its own well from that time. The house was put on the mains supply in the late 1940's. The well is now incorporated into the kitchen and the present owners have observed water levels within it since 1982. During this period the well was first assumed to have dried about 5 to 6 years ago. Since this time it has dried for some part of each year and, for example, was dry from September to January in both 1989 and 1990. In 1991 the well was dry from July to December and on our visit in January 1992 was dry again.

It should be noted that the evidence of any increase in numbers of dried wells may have been masked by the large scale transfer from private wells to piped supply in the late 1940's.

Tracer Test

It has been reported that a tracer test carried out by Wessex Water Authority at Cherhill Borehole (D), outside the surface water catchment, resulted in the tracer being recorded at Swallowhead Springs (E), indicating a connection and flow path between the two. Individual groundwater flow paths in chalk can be at considerable variance from the overall flow pattern and this is not an impossible event. However we have not found any supporting evidence or witnesses for this test. Also, geologically the connection appears extremely unlikely as Cherhill borehole is abstracting from the Lower Chalk and Swallowhead Spring appears to discharge from the Middle and/or Upper Chalk. Hydraulic evidence, from groundwater levels at Cherhill, whilst not conclusive, also indicates strongly that this west to east connection is unlikely.

4.4 Factual Data

The Upper Kennet is underlain entirely by the Chalk. Water levels in this aquifer are monitored by a large number of boreholes located across the catchment. Figure 4.3 shows the location of many of these boreholes and minimum groundwater level contours, as produced at the time, for the monitoring period up to and including 1974. Figures 4.4 and 4.5 show the minimum groundwater level contours for the drought years of 1976 and 1989 respectively.

Groundwater levels between Uffcott and Winterbourne Bassett do not appear to be significantly different on each of the three figures. However, at Winterbourne Monkton, in 1989, groundwater levels appear to have been around 5m lower (at 140m OD) than in both 1976 and historically. Slightly further downstream, to the west of the river at Avebury, groundwater levels did not fall below 140m in 1989 although they did in 1976. The groundwater catchment divide may have moved slightly eastwards in 1989 relative to 1976 and before, although the interpretation of the contours in this area is not definitive.

Groundwater levels in the vicinity of West Overton do not appear to be different in each of the three figures. The nature of the southern groundwater catchment boundary, south of West Overton appeared to have changed significantly in 1989 compared to 1976 and prior to 1974. However, further analysis of these data revealed that the record in this area is not reliable.

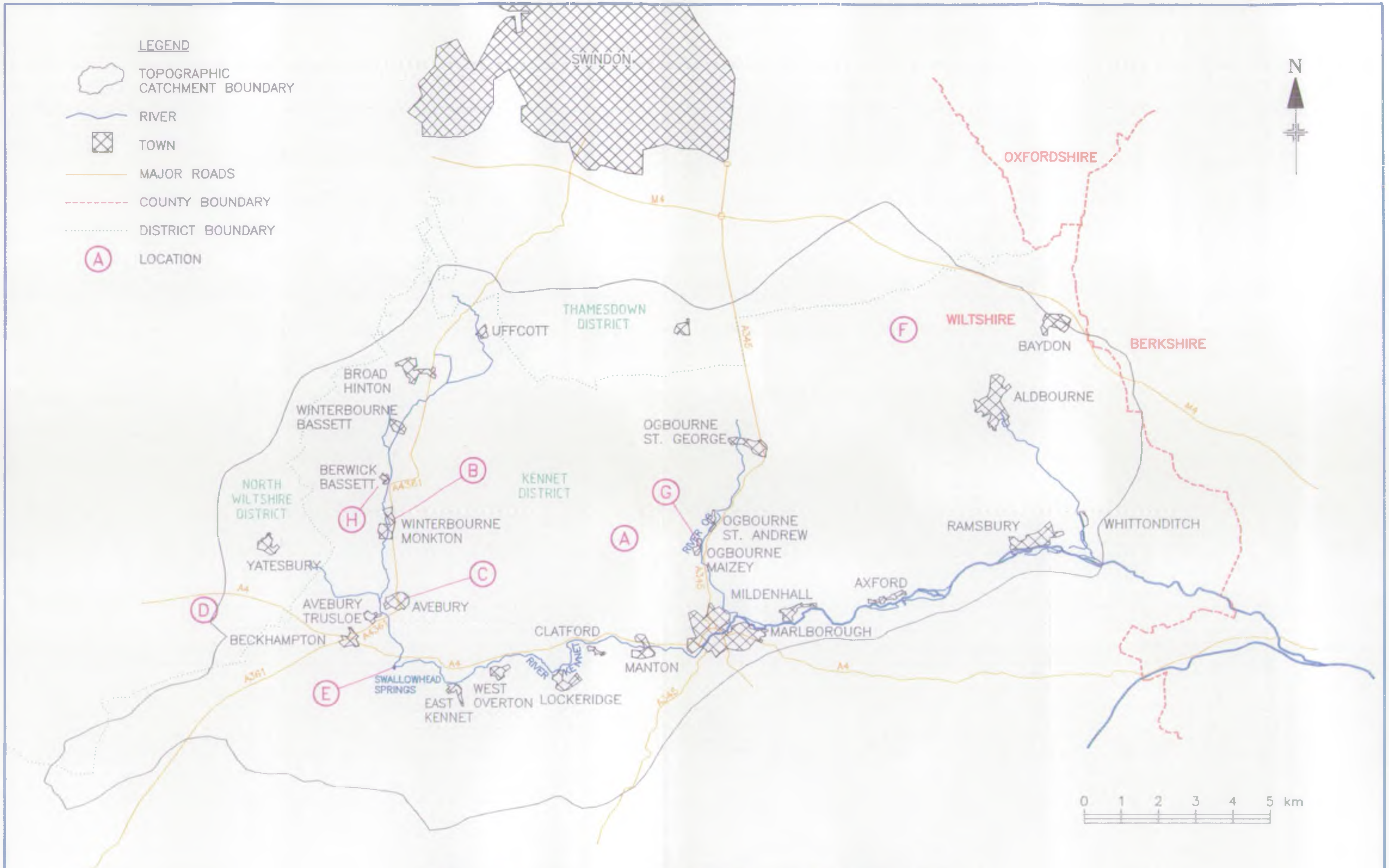
In the eastern part of the catchment, and to the north of the river, groundwater levels appear to have been similar in 1989 and, apart from certain areas in the interfluves where levels in 1989, appear higher than those in 1976.

Figures 4.6 to 4.8 indicate the minimum groundwater levels for each year of record, as recorded at Aldbourne Warren Farm (F), Well Cottage (G) and Berwick Bassett (H). These each indicate that the lowest groundwater levels in 1976 were also the lowest over the period of record. Minimum groundwater levels in 1990 appear to have been lower than those recorded in 1989 and the three year period from 1989 to 1991 is the lowest over the record.

4.5 Summary and Conclusions

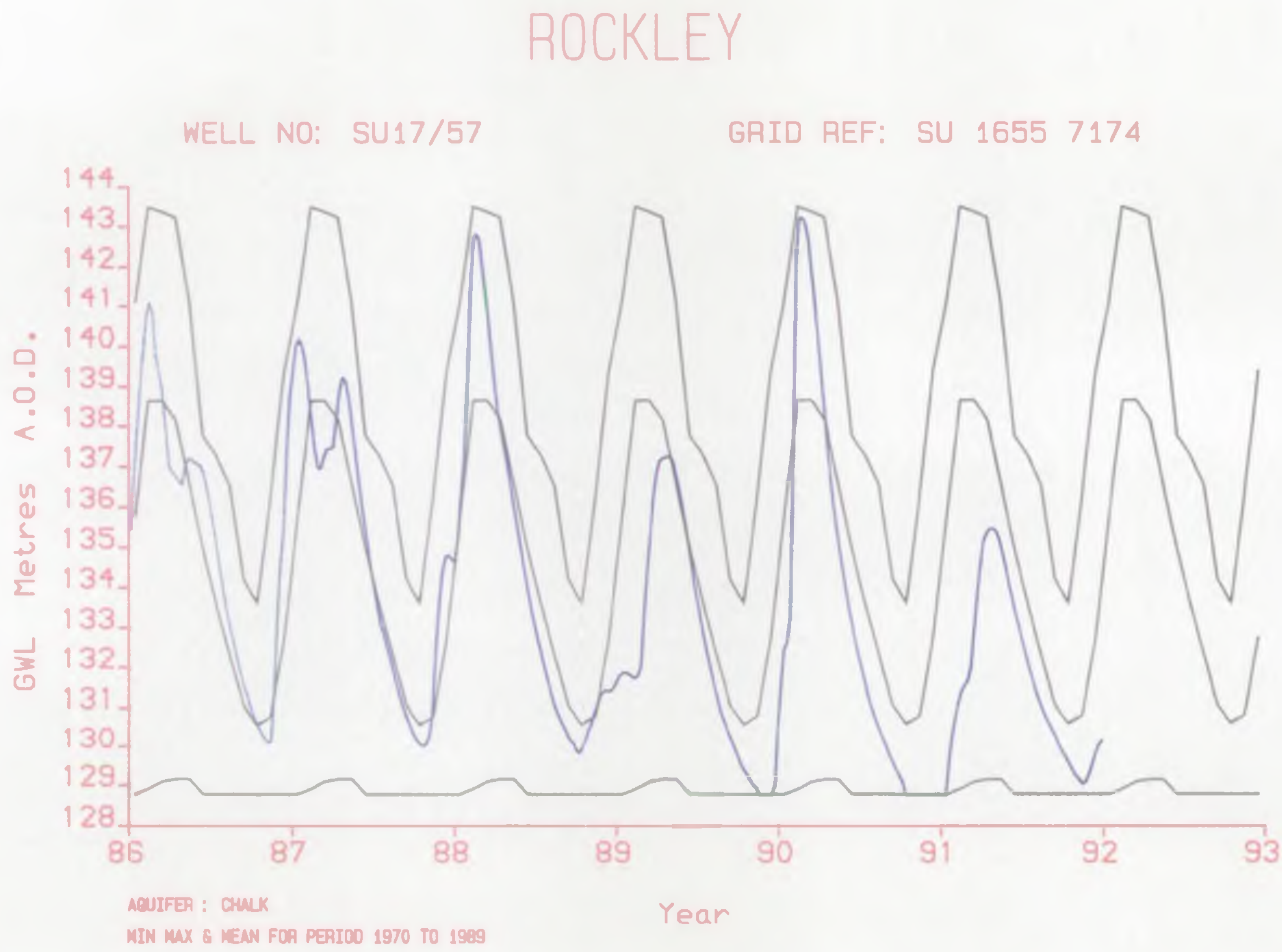
Wells in the Kennet catchment have been deepened following the drought years of 1921, 1931 and 1946. One well in particular, at Swan Cottage, appears to be experiencing lower sustained water levels than any previous time over the period from the early 1700's to 1948. There is evidence from other wells that they are also recording historically low levels. In recent years many wells have been replaced or deepened by boreholes.

In general, minimum groundwater levels in the Kennet Valley in both 1989 and over the period of record prior to 1974 appear to have been very similar to, but slightly higher than, those recorded in 1976. Minimum levels in 1990 appear to have been lower than recorded in 1989. There is no strong evidence for any change in the distribution of minimum groundwater levels over the catchment between 1974 and 1989.



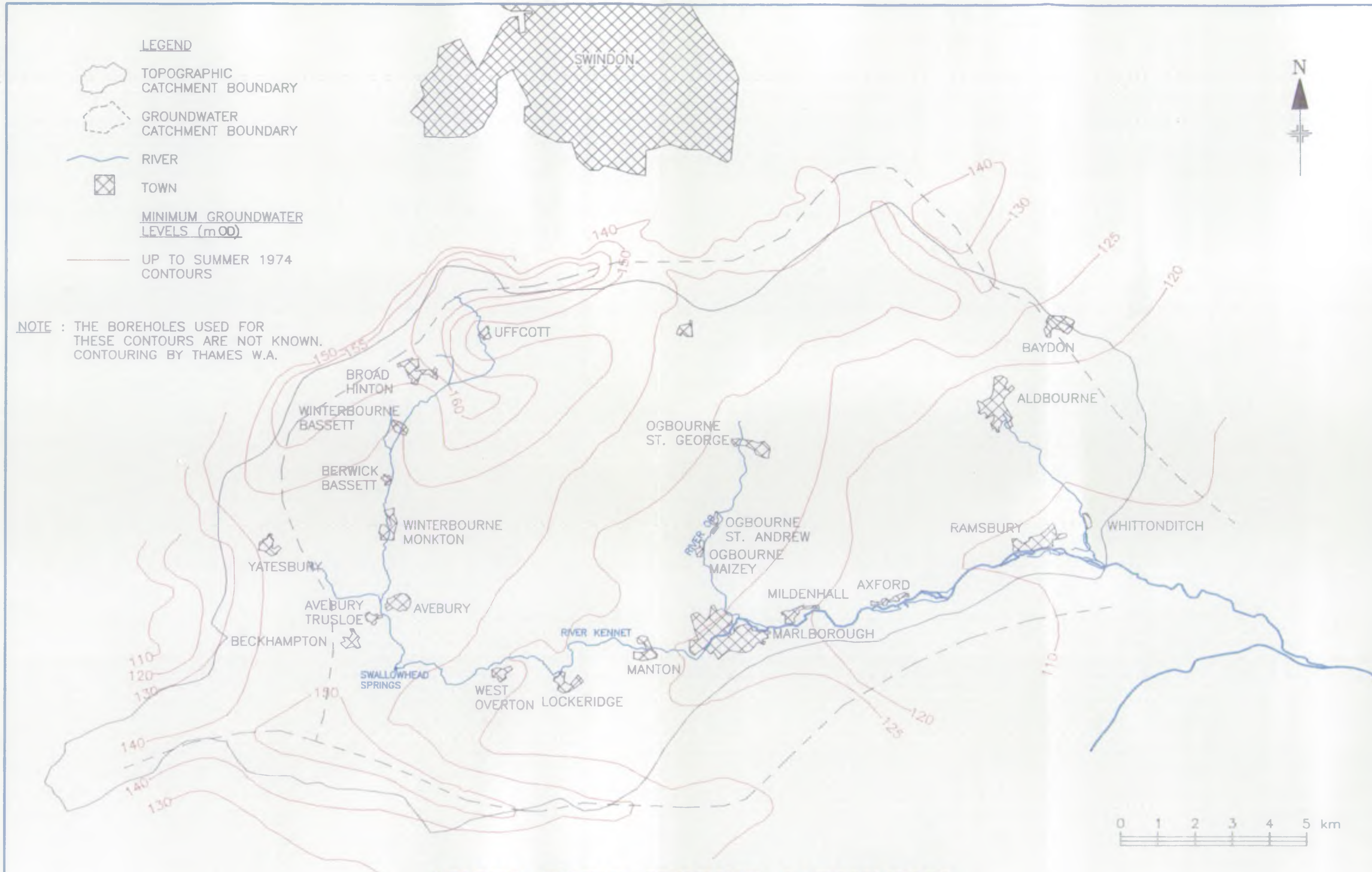
UPPER RIVER KENNET CATCHMENT
GROUNDWATER LEVELS : LOCATION PLAN

FIGURE 4.1



ROCKLEY WELL HYDROGRAPH

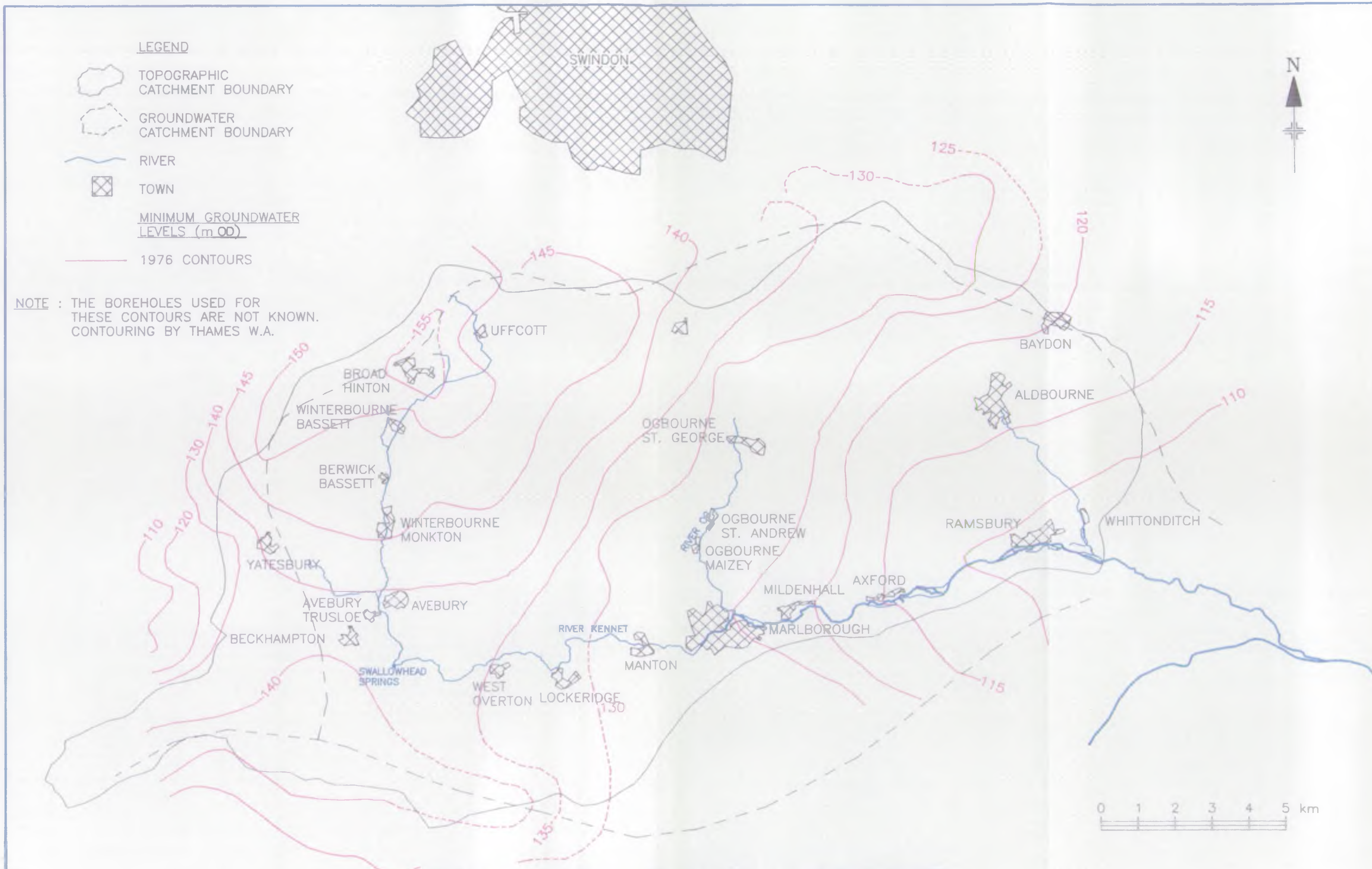
FIGURE 4.2



UPPER RIVER KENNET CATCHMENT

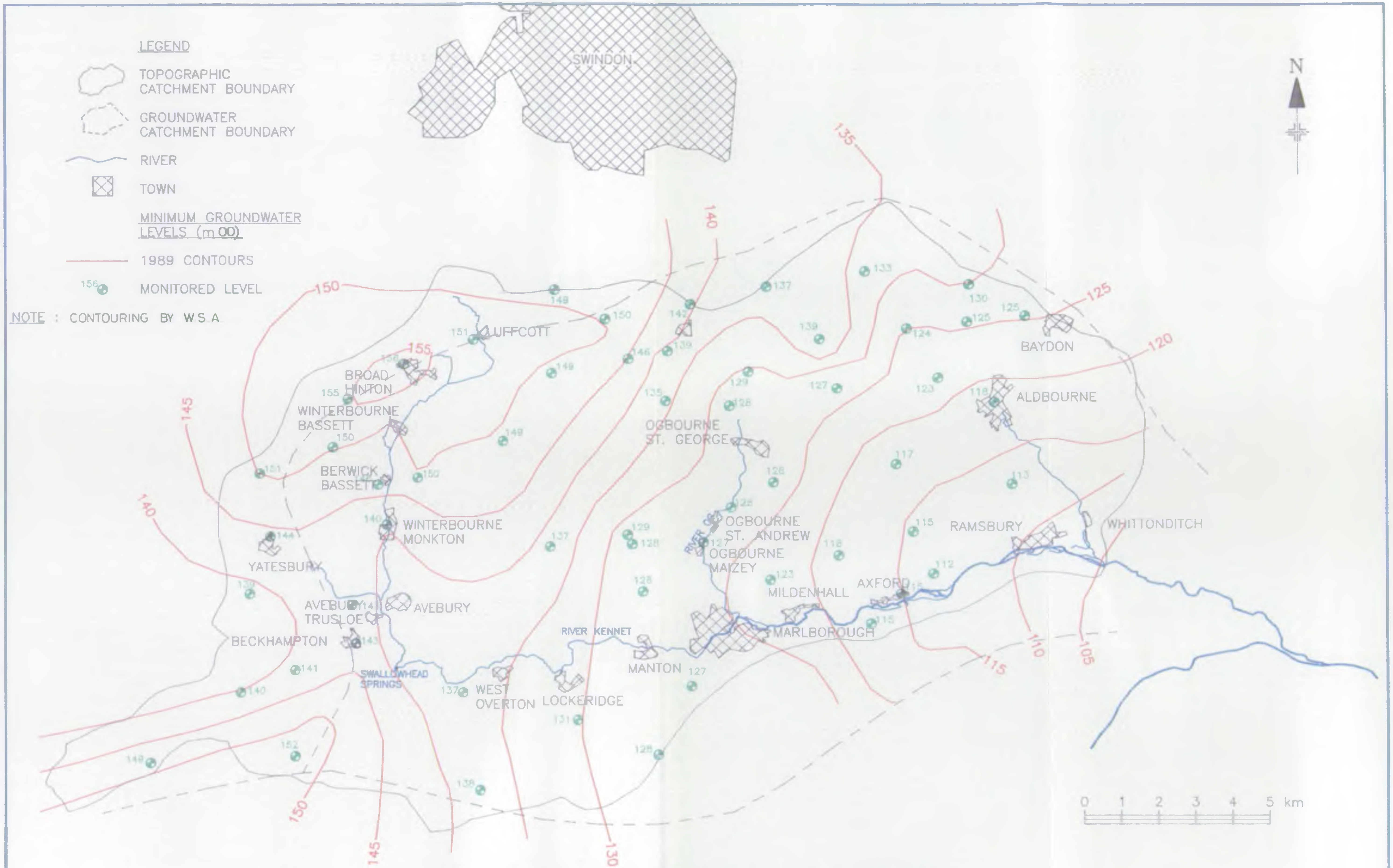
MINIMUM RECORDED LEVELS – PRE 1974

FIGURE 4.3



UPPER RIVER KENNET CATCHMENT
MINIMUM RECORDED LEVELS – 1976

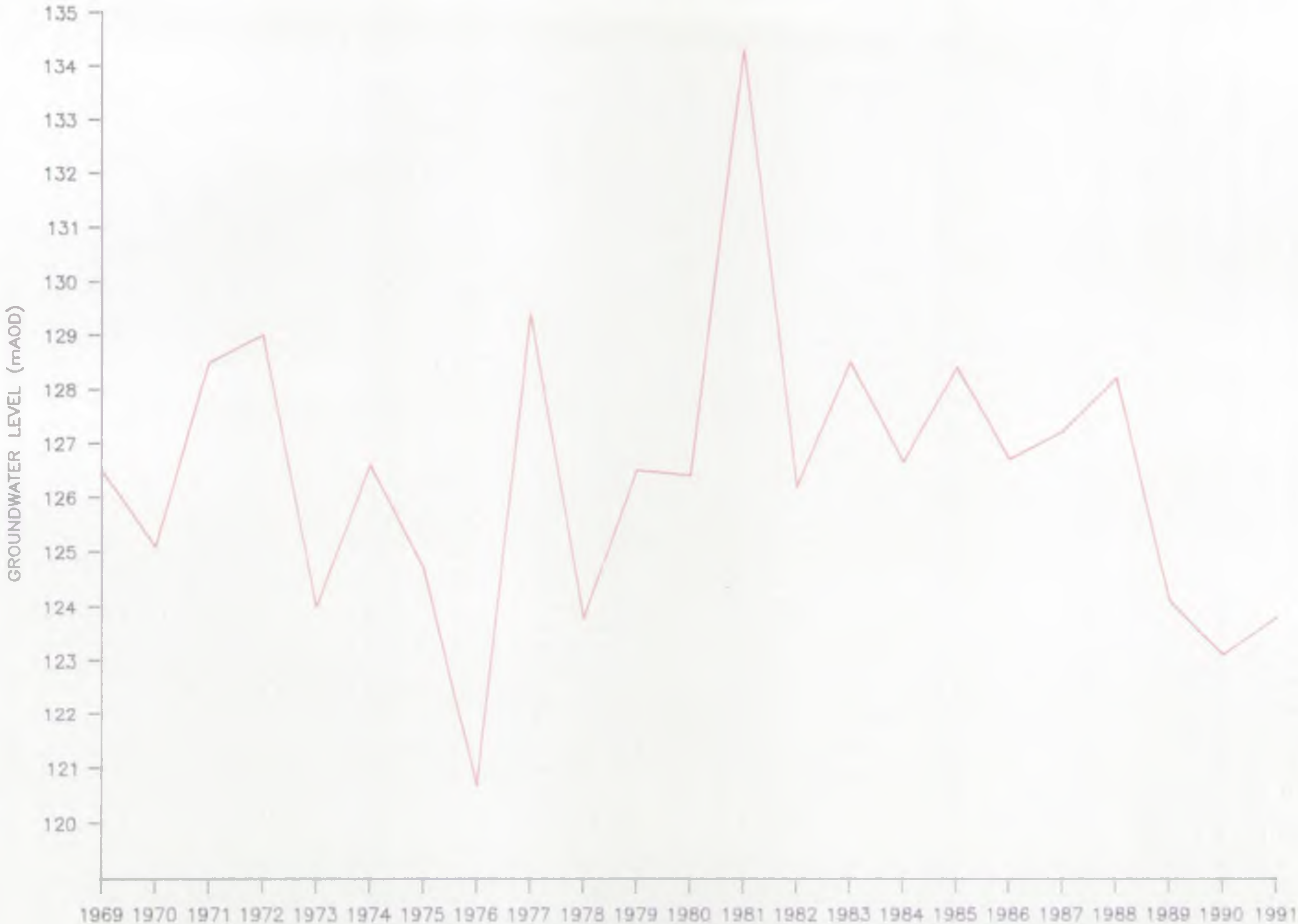
FIGURE 4.4



UPPER RIVER KENNET CATCHMENT
MINIMUM RECORDED LEVELS – 1989

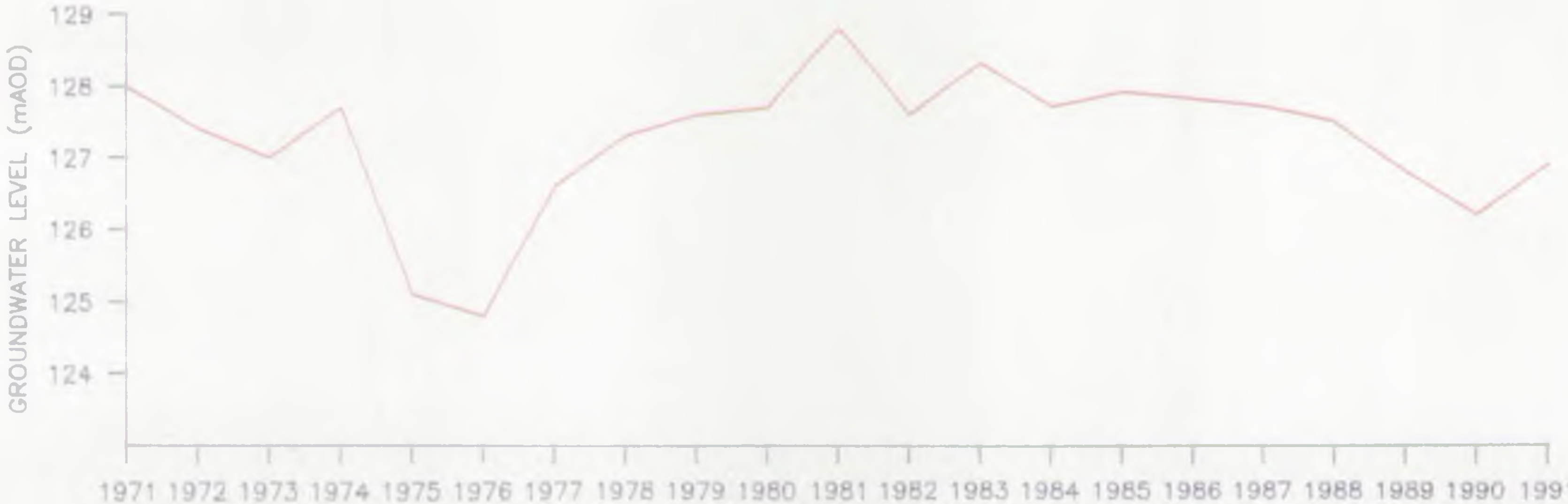
FIGURE 4.5

21/05/92 - 13:31 ---SG File-\KENNET\FIG4-5



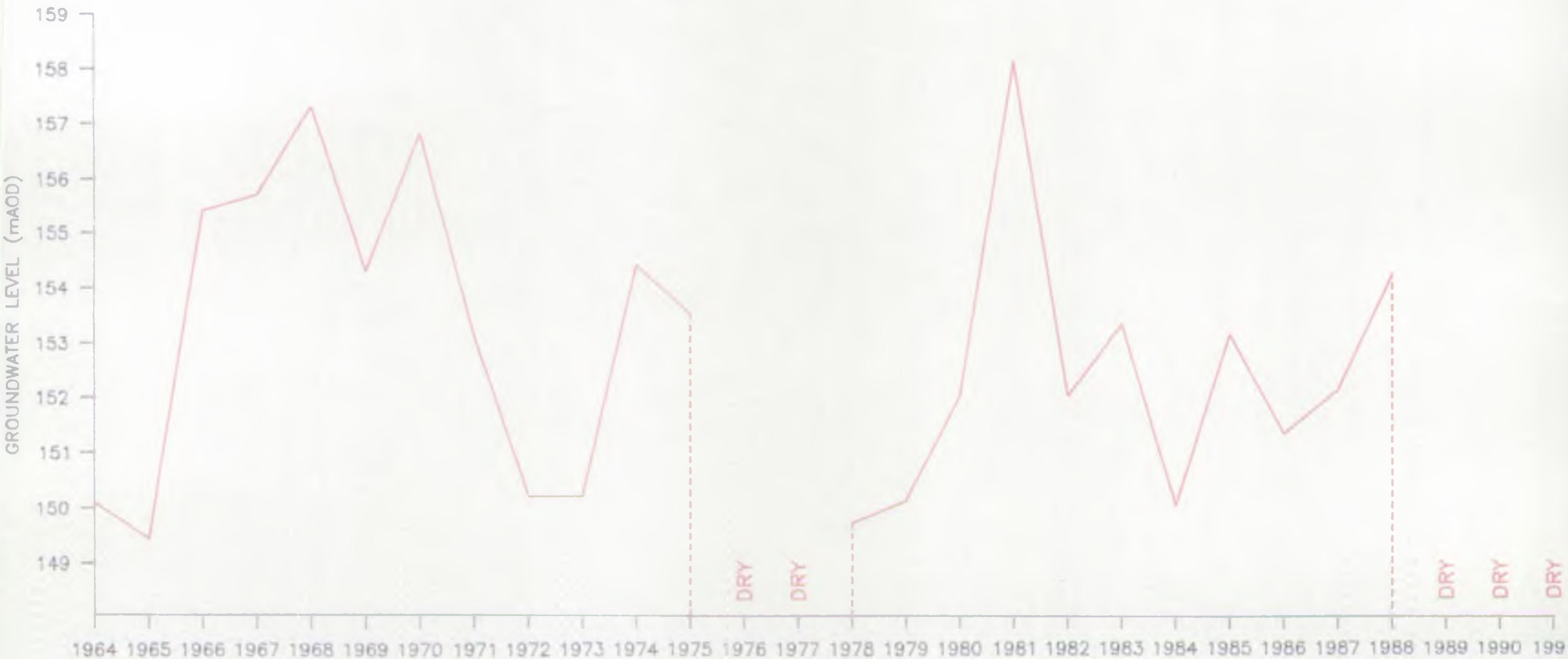
KENNET - WELL REF. SU27/20 ALDBOURNE WARREN FARM - LOCATION F
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.6



KENNET – WELL REF. SU17/86 WELL COTTAGE, OGBOURNE MAIZEY – LOCATION G
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.7



KENNET - WELL REF. SU07/11 BERWICK BASSETT - LOCATION H
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.8

5. SURFACE WATER FLOWS

5.1 General

This section considers the evidence for historical trends in:

- surface water flow characteristics
- river levels
- the upper limits of perennial flow.

The river catchment can be divided into five distinct reaches in order to examine flows, as shown on Figure 5.1 and discussed below:

- The Avebury "Winterbourne" reach comprises the whole of the north-south orientated ephemeral reach from the upstream flow source near Uffcott to the Swallowhead Springs (A). This reach is underlain by the relatively low transmissivity Lower Chalk. Above Winterbourne Bassett the stream is considered to flow only in response to high rainfall episodes and there is relatively little contribution from baseflow. The Yatesbury Bourne, a tributary of this reach, enters the main channel at Avebury Trusloe.

- The Marlborough reach is defined as that flowing eastwards from Swallowhead Springs to Marlborough. This reach has dried periodically in the historical past and one of the main issues of this study is to consider whether the nature of the flow regime in the reach has changed over the historical record.

- The Ramsbury reach stretches from Marlborough to the downstream limit of the Upper Kennet catchment at Knighton Gauge (B), downstream of Ramsbury. This is the only perennial reach in the catchment.

- The River Og subcatchment drains from north to south to the Kennet at Marlborough and, as the name suggests, is a naturally ephemeral or 'bourne' river over nearly all of its length.

- The Aldbourne is also considered as a separate reach. This sub-catchment drains north-west to south-east to the Kennet, just upstream of the Knighton gauging station. The Aldbourne is also nearly all ephemeral in nature.

Surface water flows in the River Kennet are a product, almost exclusively, of baseflow from the underlying chalk groundwater. The magnitude of base flows are dependent on:

- the location and nature of fissures, as flow paths for groundwater inflow

- the head difference between the groundwater table and the river bed or surface water level.

If groundwater levels fall below the river bed level this can produce downward flow from the river to the underlying aquifer.

A graph of the variation in groundwater levels with time is shown in Section 4 (Figure 4.2). This indicates a typical annual variation at Rockley (C) of 10 to 15 metres. Large variations in groundwater level, combined with a gently sloping river valley have resulted in extended stream reaches of an ephemeral nature. These are a natural feature of many rivers in Chalk downland.

5.2 Historical Perspective

The Upper Kennet is an ancient landscape with many man-made features of Neolithic age. The largest of these is Silbury Hill (D) near to the Swallowhead Springs and constructed approximately 2600 BC. One theory is that this, and a similar although smaller 'hill' in the grounds of Marlborough School (E), were built to mark the location of major spring sources.

The earliest written reference found to the upper limit of the Kennet is from Leyland, one of Henry VIII's chroniclers, from the early to mid 1500's. He notes that the 'Kennet risethe north-north west as Selbiri hille bottom ...'. This may be at or even above the Swallowhead Springs. Hulme, writing in 1881 in 'The Town, College and Neighbourhood of Marlborough' notes that 'The true source of the Kennet is some five miles away to the north (of Swallowhead Springs).... but all this upper portion is often, in dry seasons, waterless, while the Swallowhead Springs appear to yield a perennial supply, though there is a legend that the Kennet, on its course through Marlborough, had been a dry river bed for so long on one occasion that potatoes were planted and finally dug, where one normally expects to see a watercourse.' The reference to potatoes indicates that this dry period occurred after the introduction of the potato to Britain in the late 1500's.

Andrews and Davy's Map of Wiltshire (1773) shows the location of the mills along the river. The most upstream is Overton Mill (F), which does not appear on an early Ordnance Survey map of 1817. Clatford Mill (G) was still in existence, but long disused, in the early years of this century and finally burnt down in 1917. These were probably flour mills; their presence does not indicate that the river flow was perennial as mills were often operated with the aid of hatches to hold up and pools to store flows. However, they do suggest that flows were sufficiently reliable for commercial operation, at least on a seasonal basis.

Water meadows used to be operated in the Upper Kennet above Marlborough, probably starting in the 1600's, and continued until around the First World War. The furthest upstream water meadow was also at West Overton, near to the Overton Mill. Water meadows were operated by a network of hatches and drains which resulted in a slow moving sheet of water flowing across the meadow. The meadows were flooded periodically during the winter period to prevent ground freezing and promote early growth of grass.

The impact of water meadow and mill operation on the nature of the catchment are considered in Section 12, which also includes a plan showing the location of all those identified to date. In the context of assessing surface flow rates, the presence of these structures does not prove that flows at that point in the river were perennial but does indicate that flow, at least over the winter period, was sufficiently reliable to justify a significant capital expenditure.

A further early reference to surface flows is quoted in a 'Report of the Marlborough College Natural History Society' (EGH Kempton, 1956) which notes that the Kennet was '... dry downstream as far as Marlborough as long ago as 1855'.

The next references to surface flows in the river are from 1922, related to a drought period and reduced flows in 1921 and 1922. The Thames Conservancy District Inspector reported on 3 December 1921 that the river bed was dry to Preshute (H) and the upstream location of any water (possibly standing) was at the Marlborough bathing pool. The water depth at Marlborough Bridge (I) was 12cm only.

Hampson (1958) reports that the river was next dry to Preshute in 1929.

The next years for which information is available are 1934/5, another drought period. The upstream location of flow was reported as being 50 metres above

Marlborough School (E) in October 1934 and in general the flows in this upstream reach were considered to be worse in 1934/5 than in 1921. The upstream location of flow in the River Og was reduced to Bay Bridge (J) in July 1934 and flow was also reduced in the Summer of 1935.

A detailed record of the sources of the Kennet and its tributaries in 1933 and 1934, as logged in the Annual Report of the Marlborough National History Society, is summarised below:

Oct 1933	-	Dry above Lockeridge, shallow flow at Fyfield (K).
Dec 1933	-	Source marked by strong springs at Fyfield Church (K).
Feb 1934	-	River bed dry at Preshute Bridge (H) approximately ½km upstream of Marlborough College.
Mar 1934	-	A trickle only at Cow Bridge directly to the west of the College (I).
May 1934	-	Flow recovers from Preshute (H) to Fyfield (K) in the space of 15 days.
Aug 3 1934	-	Flows from Fyfield springs disappear at Manton.
Aug 19 1934	-	No flow at Preshute.
Nov 1934	-	Dry to Marlborough College, flow at Cow Bridge is 3m across and only a few centimetres deep.
Dec 1934	-	Flow at Fyfield but no flow downstream at Manton. This is the last record for the Kennet in this series.

The record notes that the Og was dry at Bay Bridge, 1500m above the confluence with the Kennet, from May to November 1934. The river at Lockeridge was dry from October 1933 and Swallowhead Springs from Summer 1933 at least until the date of the article in December 1934.

Other references in the same period note that the source of the Aldbourne was reduced to the cress beds at Whittonditch (L) in July 1934, it appears until May 1935. However, in December 1935 flow returned along the full length of the Aldbourne as far upstream as the town of the same name. In January 1936 flow in the River Og was reported as being along '... the full course ... from Ogbourne St George and from Draycott Foliat (M) above'.

In 1947, Colonel GK Maurice of Manton near Marlborough published 'Passing of a River - An Obituary'. This interesting and informative article describes the nature of the Upper Kennet River in the late 19th and early 20th century, experienced as a boy and young man and recollected by the author when in his sixties. The recollections are summarised below:

- The river in the late 19th century at Manton, 'flowed under the bridge deep and smooth, brim full in the longest droughts of summer'.

- He reports a number of actual and near drownings, each of which appear to have occurred in the river upstream of Marlborough. The furthest upstream location was at Wheeler's Pool, named after the drowned man and believed to be midway between Manton and Clatford.

- The author fished for trout along the Upper Kennet between Clatford and Marlborough from the turn of the century to the First World War and then spent a long period out of the country. The largest fish, caught from the Mill Pool at Clatford, were 5 lb and 6 lb.

He describes the impact of a recent drought, believed to be 1944-46. Of equal interest however, he describes the gradual reduction in river flows which he had witnessed in the period leading up to the drought and his efforts, through river narrowing, to control these changes. He notes that 'every summer now when the rainfall is below average the river dries almost to the garden where I played as a child (Manton)', and that the change in flow regime has been gradual '... taking more than a quarter of a century ...'

The record of changes in the floral character of the river, as recorded by Colonel Maurice over the same period is considered in Section 7.2

Colonel Maurice was also involved in the Enquiry for the Avebury Water Scheme in the 1940's and notes that there is '.. a mass of evidence collected from local inhabitants about the dwindling of the Kennet over the last 30 years'. A formal objection to the scheme was submitted on the grounds that, 'The sources and flow of the River Kennet have been constantly diminished within recent years so that the flow of the said river is hardly sufficient for the agricultural and other interests of the Objectors'.

The next record found is from October 1959, regarding a dry reach from Pan Bridge (N) to Fyfield (K), although a slight flow was recorded upstream from Avebury.

We have no reports of a reduced length of flow in the river during the 1960s, but from 1972 to 1990 the upstream and downstream source of the Kennet was recorded each year and these data are reproduced in Table 5.1.

Table 5.1 - Source of the Kennet

Year	Highest	Lowest
1972	-	Fyfield
1973	Berwick Bassett	Fyfield
1974	Uffcott	Lockeridge
1975	Uffcott	Fyfield
1976	Fyfield	Marlborough College
1977	Winterbourne Bassett	No Data
1978	Uffcott	U/S Lockeridge
1979	Uffcott	U/S Clatford
1980	Uffcott	Silbury Hill
1981	Uffcott	U/S Lockeridge
1982	Uffcott	U/S Lockeridge
1983	Uffcott	Fyfield
1984	Uffcott	Fyfield
1985	Uffcott	Fyfield
1986	Uffcott	Fyfield
1987	Uffcott	Swallowhead Springs
1988	Uffcott	Clatford
1989	Uffcott	Manton
1990	Uffcott	Manton

In 16 of the 18 years for which data are available the lowest source of the river was downstream of Lockeridge. In nine of these years the source was at Fyfield where there are known to be significant spring outflows to the river.

5.3 *Public Perception*

There is a great deal of concern in the Kennet catchment with regard to reduced flows, particularly in the reach of the river to Marlborough. There is also a general perception among the local population that the Swallowhead Springs are the natural perennial source of the Kennet River. The concern for the river, as reported in the section above, is not a recent phenomenon and the issue is recorded as being of great importance in the 1940's, culminating in the Avebury Borehole enquiry in 1948.

Current concerns were first voiced publicly in February 1989 at a Public Meeting on the issue held in Ramsbury and attended by over 50 people. A further Public Meeting in January 1991 was attended by over 150 people and, following this meeting, Action for the River Kennet (ARK) was formed, with the brief to lobby for improvement to the character of the Upper Kennet catchment.

Wiltshire County Council, the Salmon and Trout Association and the Kennet Valley Fisheries Association have also expressed their concerns as to the low levels experienced in the river.

A summary of the local views, as recorded by ARK in their report of 1991, is given below:

- There are a number of reports as to a change in the time of year at which the river dries below Swallowhead Spring. The following, from a local farmer, is typical '... the river ... used to dry up each year (below Swallowhead) in late October up to the end of the 1970s. The Swallowhead and other springs below it would start to run again in December. In recent years, since the mid 1980s and well before the 1989/90 drought, it has dried earlier and earlier each year'.

- Spring river levels are quoted as having fallen by up to a metre between the 1970s and 1980s.

- A decline in flows below Marlborough during the 1980s is reported with an estimate of 30 per cent reduction.

- The timing of baseflow recovery is reported as having changed over the past 5 to 6 years. Whereas flow recovery would commence in December, the river in recent years has remained low through much of the winter.

- It is also noted that levels are high for a shorter period, typically from May to July only in recent years.

- Levels are considered to have dropped on average by an estimated 10-15cm on levels of 20 years ago.

Mr Swanton of Lockeridge has, like many other contributors to the study, lived in the area for over 30 years and has a long family history in the valley. He has stated in newspaper interviews in 1984 and 1990, that the nature of the upper part of the Kennet above Marlborough in recent years was consistent with his own experience and that of his father over a 75 year association with the river. He used to swim in the Old Mill Pond at Overton as a boy. The pond was a part of the river deepened for water supply to the mill and this feature was lost when the river reach was straightened in the 1950's.

We have had discussions with a number of other local inhabitants and NRA Officers with regard to flows in the Upper Kennet. These are summarised below:

Peter Ludlow - Secretary KVFA

- We visited the Aldbourne catchment and Mr Ludlow pointed out where, downstream of Aldbourne Village, former water meadows had not been inundated in the last 4 to 5 years (O) and where livestock trampling was contributing to the channel losing its distinction (P).

- Mr Ludlow confirmed that a water cress farm (Q) used to operate on the Aldbourne at Wittonditch but was closed in 1987.

Phil Chatfield - Former NRA Local Pollution Officer

- Mr Chatfield confirmed that there is a reach of the Kennet Winterbourne from Berwick Basset (R) to Monkton which may flow quite strongly but with the total flow lost through the base of the stream by Avebury.

- There are major springs in the river just to the west of Fyfield sewage treatment works. The works were located here, in part, to increase the availability of dilution flows.

- The top of the River Og channel has been ploughed for cereal production.

John Hounslow - River Keeper on the Crown Estate (S) downstream of Marlborough

- Mr Hounslow considers that his reach has declined from a very good to a poor river over the last 2 to 3 years. He believes that the fundamental reason for this is a reduction in flow velocity.

- In 1984-6 Mr Hounslow narrowed part of his reach of the river by 1-2m in order to try and preserve flow velocities. He has also recently (1992) introduced 150 tonnes of sarsen stones into the river in a further effort to increase velocities.

- He does not believe that river levels have been high enough over the last 6 years to flood the old water meadows.

- He considers that the recovery of the river from late year low flows is not as rapid as it used to be. He also notes that the drainage capability of the river has improved in the same period and the river no longer floods the road.

- The River Og was, Mr Hounslow understands, considered as the spawning ground for trout along his reach of the river. There was a traditional day, at the end of the fishing season in October/November, when the Og was cleared of weeds and fish up to Ogbourne Maizey. This was a very popular occasion for the local populace as many large fish could be caught. It is interesting to note that (i) river flows are generally at or about their lowest in October/November and (ii) flows in the Og, as monitored at the gauging station at the base of the stream, have been at or close to zero over the last 2-3 years.

- There used to be a fish farm at Ogbourne Maizey 30 to 40 years ago. It is understood that this was a trout farm but this has not been confirmed. A trout farm would need significant and reliable flow to be sustainable.

- The Mildenhall fish farm, downstream of Marlborough, used to produce 18 tonne of fish per year. This yield has reduced substantially prior to a major pollution incident putting the operation out of business (see Section 6). Mr Hounslow considers that the reduced flow in the river was the main contributor to the reduction in trout yield.

Stanley Philpott - part time river keeper for East Kennett to Clatford between 1927 and the outbreak of war.

- The river reach between East Kennett and Manton was managed during this period and produced many trout. This correlates well with the recollections of Colonel Maurice (1947). The trout were removed from the river each summer down to Clatford when it could no longer sustain them and put in a storage pond at Ramsbury.

Frank Smith - West Overton

- The river used to flood regularly in Lockeridge, and West Overton would be cut off from the A4 road by high river levels. This continued until dredging operations improved river drainage in the 1960's and 1970's.

As a result of the study we have received a large number of photographs of the upper catchment. Some of the more interesting of these are described below:

Marlborough College Archive

- Dry river bed at Manton Bridge (T) circa 1932.

- Dry bed at Fyfield Bridge on October 23 1934.

'Fishing in the Making' - Lancelot Peart (1930s)

- Fishing above and below Mildenhall.

Neville Mutter - ARK

- Extensive flooding on roads by the Kennet near Ramsbury - 1940.

- Flooding on water meadows near Ramsbury - 1954.

John Hounslow

- Bank full river flow downstream of Marlborough - Spring 1982.

- River narrowing exercise - 1986.

John Russell

- Good water levels in the river at Clatford Bottom - Spring/summer 1965.

Alastair Service - ARK

- Flooded water meadows at Fyfield - early spring 1906.

- Flooding in Lockeridge High Street, 1940.

- 2lb 9oz trout - Lockeridge 1968.

- 5lb trout - Lockeridge 1981.

5.4 *Factual Data*

Hydrographs

The River Kennet is gauged at Marlborough (U) (since 1972) and Knighton (B) (since 1963). The Og is gauged at Marlborough (V) (since 1980) and the Aldbourne at Ramsbury (W) (since 1982). The longest record of continuous flows in the upper part of the catchment is therefore at Knighton which extends back almost thirty years.

The wettest of the gauged catchments is that of the Kennet to Marlborough. The (1941-70) average annual rainfall is 817mm over a catchment area of 142 km^2. The Og has an average rainfall (1941-70) of 804 mm per year over an area of 59 km^2. The Kennet to Knighton, with an area of 295 km^2 has an average rainfall of 800 mm.

A sample of selected three year hydrographs of daily mean flows for the River Kennet at Knighton (B) is shown in Figure 5.2. The vertical axis has a logarithmic scale. The hydrographs for four periods are shown: 1964-66; 1974-76; 1980-82 and 1988-90. Included in this selection are both the wettest (1974) and driest (1964) years in the history of the gauging station, and the years with the highest (1966) and lowest (1976) flow volumes.

It is apparent from the plot that flows in the summer of 1976 were exceptionally low. Apart from 1976, the lowest summer flows shown occurred in 1965. Autumn and winter flows have been at or near their lowest in recent years. The current (January 1992) flow is the lowest ever recorded for this month.

Two other points could possibly be drawn from this plot, both concerning the shape of the hydrographs. The first point, perhaps the more obvious, relates to the 'peakiness' of the catchment response. In the traces for both the 1960s and 1970s the hydrographs appear much more spiky than do those of the 1980s. While all traces are dominated by a slow baseflow response, the 1960s and 1970s have a much larger number of flashy responses to rainfall lying on top of the baseflow response: the hydrographs of the 1980s appear more subdued and smoother.

The Knighton gauge was vulnerable to 'drowning' caused by weed growth, during high flow periods. This problem has been dealt with in recent years but may have affected earlier data and been a cause of the change in river character noted above.

The second point is more tenuous, and relates to the gradient of the recession curves. In all three years of the hydrograph shown for the 1960s, the recession curves are less steep than those of later years. Possibly, the recessions of the 1980s are the steepest, but the flow recessions of 1974 and 1988 overlie each other almost perfectly.

The River Kennet at Marlborough has a flow record ten years shorter than that further downstream at Knighton. Figure 5.3 shows four, three year hydrographs, two each from the 1970s and 1980s. 1976 again stands out as having extremely low flows, at the limit of sensitivity of the gauging station. Apart from this, and the observation made earlier that winter flows in 1990 appear exceptionally low, there appears to be little unusual about the hydrographs. This could, however, simply reflect the relative brevity of the record.

Baseflow Indices

Figure 5.4 shows a plot of the baseflow index (BFI) for each year of record, for the flows recorded in the Kennet at Knighton (this work was undertaken by the Institute of Hydrology). The BFI can be taken to indicate that proportion of a river's total flow that is derived from groundwater baseflow. Note that the Y-axis ranges from 0.8 to 1.0.

1976 can again be seen to be the outlier of the series, having a significantly lower BFI than any other year. The explanation for this can be seen with reference to Figure 5.2. Flows throughout most of the year were very low, and predominantly fed by baseflow. However, in October, November and December 1976 several large flood events occurred which account for a large part of the total catchment throughflow. Therefore a larger proportion of flow that year occurred as flood runoff, thus reducing the baseflow derived portion.

More interestingly perhaps, is the observation that the baseflow index in all of the last eleven years (1979-90) has been above the mean for the period of record. In only six of the previous thirteen years has the BFI exceeded the mean. The inference is that a smaller percentage of rainfall resulted in runoff during the last decade. This phenomenon was hinted at earlier with reference to Figure 5.2, where it was noted that the hydrographs of the 1980s appeared to be less spiky than those of the previous two decades.

Double Mass Analyses

A method of testing the homogeneity of a time series record is to plot consecutive values as a running cumulative total against a similar cumulative record of known homogeneity. This is known as a double mass plot. Figure 5.5 shows such a plot for both the total rainfall and the percolation (or recharge) for the Berkshire Downs unit (including the Kennet catchment) and Cotswolds West (including the Coln). If records are homogeneous the resulting plot will form, more or less, a straight line. The linearity of the plot can be observed by looking down the line along the plane of the page. Figure 5.5 shows strong homogeneity between the two rainfall series when observed in this way.

The plot does not prove that the rainfall series are 'correct' but does show that they are consistent with each other through time. This indicates that (i) the pattern of rainfall and percolation (but not the actual amounts) experienced in both catchment regions have been similar and (ii) there are no internal discrepancies within the data record for either catchment over this period.

In some of the following analyses the double mass plots are not entirely linear. A change to the linearity of the record indicates a change in the relationship between the two parameters. This change can be quantified and dated by considering the location and magnitude of the change in gradient. Line fitting is a somewhat inexact science and although we have quoted 'best fit' results on the basis of our line fitting, the actual level of accuracy is reflected in the ranges of possible values quoted in the summary.

The River Lambourn is the catchment directly to the east of the Aldbourne and is the next northern tributary of the Kennet downstream of Knighton. The flow record in this catchment is of great interest because the catchment is considered to be largely unaffected by abstraction, with only three small public water supply boreholes, and therefore the surface flow regime is considered largely 'natural'.

Figure 5.6 shows a double mass plot of the Berkshire Downs rainfall with surface flow as recorded on the main gauging station for the Lambourn at Shaw. The plot also compares cumulative percolation with flow. The plot shows a good straight line relation between the parameters and indicates that their relationship has remained constant. As the rainfall and percolation data are considered, from Figure 5.5, to be internally consistent, the Lambourn flow regime is indicated as being unaffected by any change in outside influence over the period of record.

Figure 5.7 shows a plot of flows at Knighton against flows at Shaw. There appears to be a change in the straight line relation during the period of record and our 'best fit' is indicated by the two lines on the graph. This interpretation translates to a relative reduction in the mean annual flow rate of the Kennet at Knighton, dated from 1969-70, of 10 Ml/d.

Figure 5.8 plots rainfall and percolation vs flow at Knighton. Again our 'best fit' indicates a break in the relation, translating to (i) 12 Ml/d dated from 1975-6 (percolation) and (ii) 13 Ml/d dated from 1972-3 (rainfall).

The line fitting is clearly an inexact science and other linear fits may be equally valid. However, the analyses do all support a sustained reduction in the flow characteristics of the River Kennet at Knighton of 10 Ml/d or so, starting from the early to mid 1970's. These analyses take no account of any changes in catchment flow characteristics which may have occurred prior to 1963.

Figure 5.9 plots rainfall and percolation against flow as measured at Marlborough gauge. This plot is more difficult to interpret as (i) there is more deviation from the line and (ii) the data period is less than 20 years. There is some indication of an increase in flow relative to percolation from 1984-85 and, possibly, a reduction in flow over the last two to three years from 1988-89. The data set is considered insufficient for any definitive assessment however and a straight line fit appears satisfactory.

Flow Accretion Curves

The change in river flow along a river on any particular day is assessed by means of spot flow gauging at various locations along the reach. The results are plotted as a graph of gauged river flow against distance along the river known as a flow accretion curve. Comparing accretion curves from different years can indicate changes in the pattern of inflow to and outflow from the river.

Historically, many spot flow gaugings were undertaken on the Upper Kennet during the mid 1970s. No relevant gaugings were undertaken during the 1980s, but some gaugings were carried out in 1991.

Flow accretion curves derived from both historical and recent gaugings are shown in Figure 5.10. It can be seen from these curves that the head of the river has been mobile over large distances, sometimes over relatively short periods of time. For example, between January and April 1973, the source of the river moved downstream approximately 5 kilometres, equating to approximately 60m per day.

Nevertheless, it appears that during the mid 1970s the pattern of flow accretion remained constant, with the profiles (in solid lines) shadowing each other up and down the flow axis. It can be seen at low flows that there are certain reaches where the river is influent, i.e. it loses flow to groundwater. These reaches are notable around Pan Bridge and Lockeridge.

Flow accretion curves from 1991 were broadly similar, particularly in the higher flow period (April and May). However, during lower flow periods there appears to have been a change in the pattern of flow accretion, identified by lines from 1991 crossing those from the mid 1970s in the area between Marlborough and Lockeridge. The significance of this is unclear. It may indicate either reduced flows both upstream and downstream of Clatford or, conversely, increased flows from the Fyfield Springs or Fyfield STW. No definite conclusions can be drawn from these spot flow data.

5.5 Flows : Summary and Conclusions

This section summarises the findings of the surface flow analyses. The causes of any features noted below are considered further in Stage Two of the Report.

Upstream of Swallowhead Springs

This reach is generally accepted as being ephemeral in nature. It is reported to respond quite rapidly to rainfall, probably due to being underlain by Lower Chalk. Other reports note that flow recorded in the upper reaches is lost to the groundwater near Avebury.

Swallowhead Springs to Marlborough

This reach has been the focus of most local concern regarding, in particular, the reduction in river levels. There is no doubt that public perceptions of a decline in river flows over the last 5 to 6 years are correct but it appears, from the available data, that these flows have remained within the bounds of normal variation. The comments and perceptions of Colonel Maurice in 1947, after the drought of 1946, bear a striking resemblance to the current public concern as to the changes in the river.

The river is recorded as having dried, in response to severe drought years, over the reach to Marlborough College in 1855 and at fairly regular, say 10 year, intervals over this century since 1921. Swallowhead Springs were reported as being the perennial head of the river in commentaries from both the early 16th and late 19th Centuries. However, a further report notes an intervening period during which the river bed in this reach was dry for long enough to be developed for potato growing.

There appear to be specific locations of major spring flow, for example at Swallowhead, Fyfield Church and near Marlborough College. There does not appear to be significant inflow in the intervening reaches during low flow periods and, at Lockeridge for example, the reach loses to the groundwater. These low yielding reaches are indicated by the rapidity with which the upper limit of flow moves between the main spring sources during low flow periods.

This historical evidence indicates that, in the long term, the perennial limit of the Kennet may move between the three main spring sources within this upper reach. It appears that, at least within this century, the river has dried to Fyfield Springs in many years and, say once per decade, has dried to Marlborough College.

The gauged data, from Marlborough gauging station and the spot flow gaugings, are for a relatively short duration and largely inconclusive. However, there is no evidence for any major change in the flow regime over the last 20 years upstream of Marlborough.

The commercial use of this reach has declined significantly in this century. There were two operating mills and a large expanse of water meadows in the reach in the 1700s. By the early 1900s the mills were disused but many of the water meadows were still being operated and the river was keepered and operated commercially for fishing. It is important to note however that the fish were removed each summer due to low water levels. The intense management of the river in this reach may, in itself, have helped to retain water levels and improve the river's appearance. This issue is considered further in Section 12.

Flooding, which used to be fairly commonplace in this reach up to and just after the Second World War, particularly in and near Lockeridge, has not recurred to any degree since the 1960s. The gauged record also shows a reduced peakiness in the flow although this may be artificial, due to changes in the maintenance of the gauge. These changes may be due in large part to the dredging works instituted in this reach in the 1950s (see Section 12 for more details of this issue).

Marlborough to Knighton Gauge

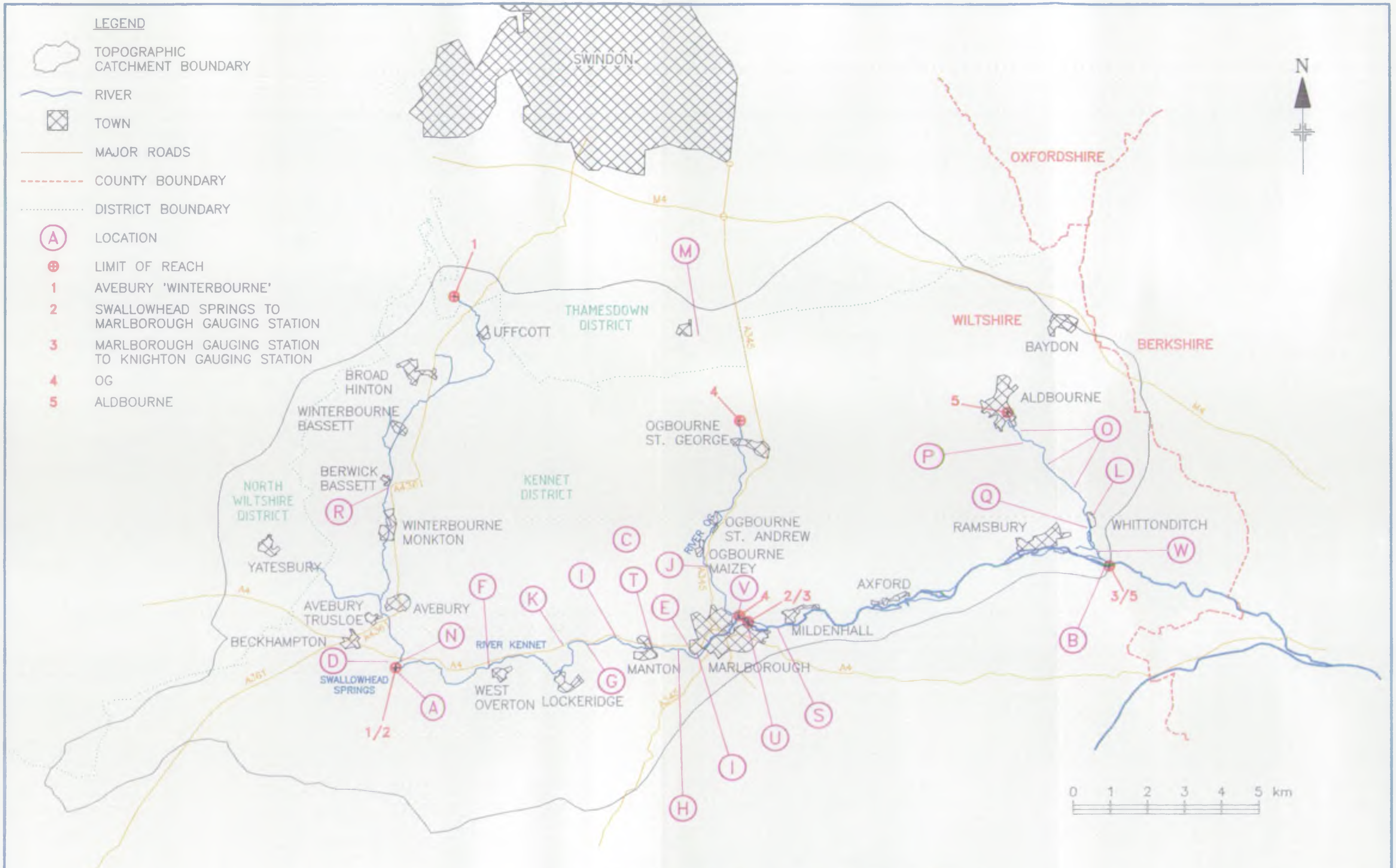
The public perception is that river levels have reduced significantly along this reach in the last 5 years and this is borne out by analysis of flows at Knighton Gauge. The detailed flow analysis, using double mass plots, indicate that there has been a consistent reduction in daily flow at Knighton which appears to date from the early to mid 1970s and be in the order of 10 to 15 Ml/d.

River Og

There is a body of circumstantial evidence as to reductions in the flow regime in the River Og catchment over the historical past. These include references to the old traditional weed cutting day in the Og during the low flow Autumn period and the river being used as a spawning area for trout. There also used to be a fish farm at Ogbourne Maizey. This compares with present day ploughing of the upstream reach and the minimal to zero annual low flows recorded at the gauging station. The flow record at the gauging station is of insufficient period to fully validate this evidence however.

Aldbourne

There is no evidence of changes in the flow regime in the Aldbourne although there is also very little data.



UPPER RIVER KENNET CATCHMENT SURFACE FLOWS : LOCATION PLAN

FIGURE 5.1

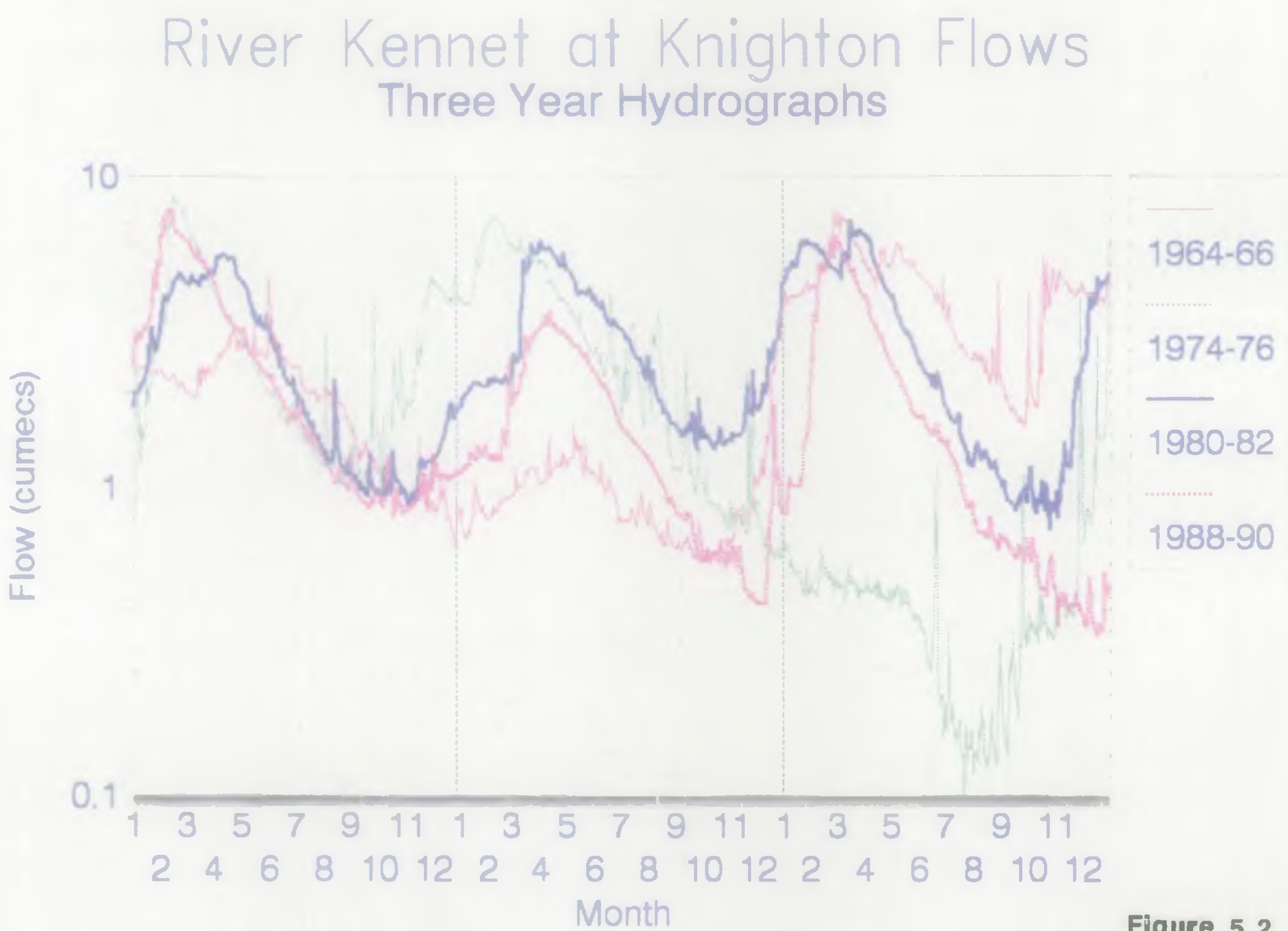
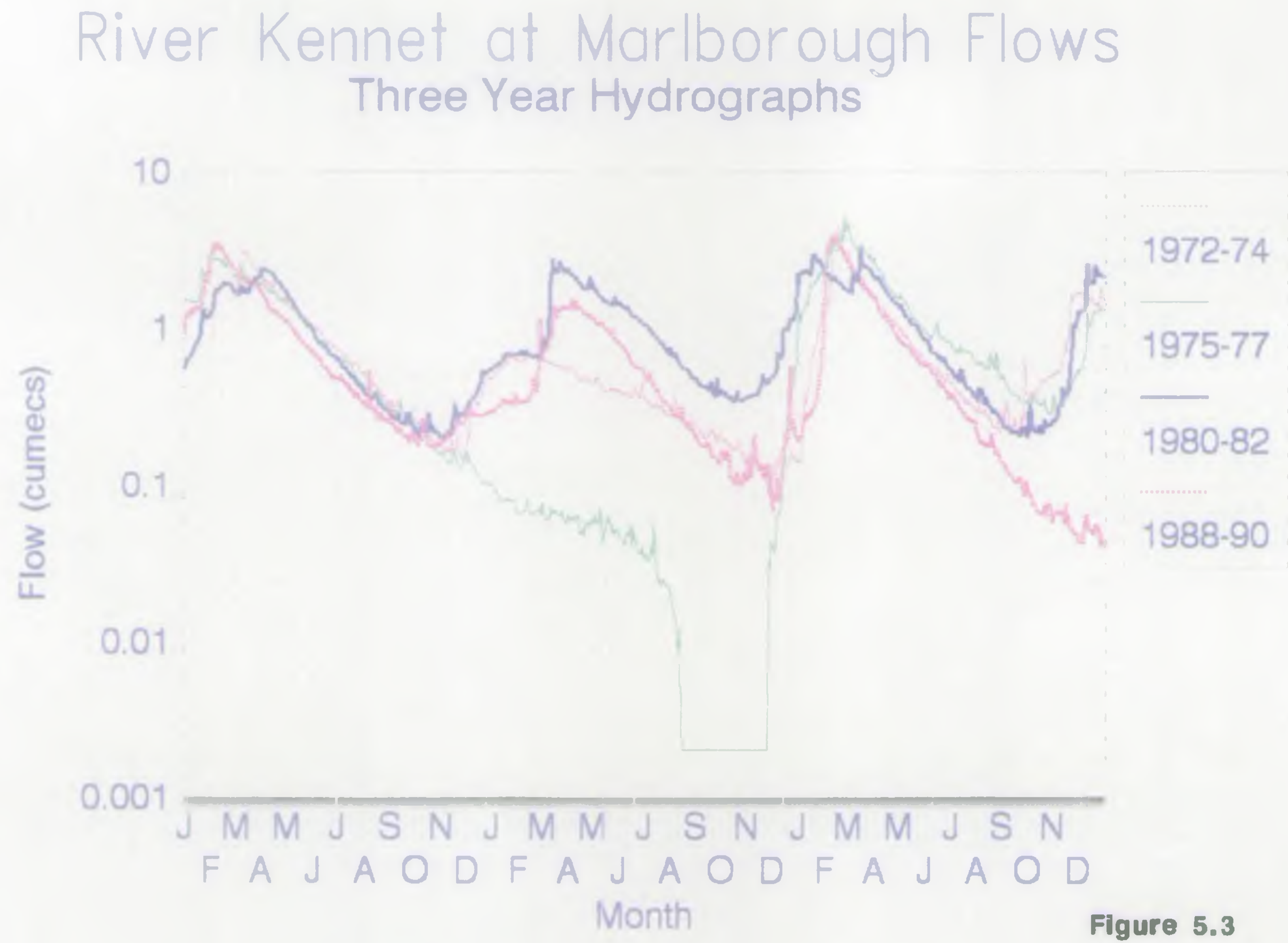

River Kennet at Knighton Flows
Three Year Hydrographs
Flow (cumecs)
10
1
0.1
1 3 5 7 9 11 1 3 5 7 9 11 1 3 5 7 9 11
2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12
Month
1964-66
1974-76
1980-82
1988-90

Figure 5.2



River Kennet at Marlborough Flows
Three Year Hydrographs
10
1
0.1
0.01
0.001
Flow (cumecs)
1972-74
1975-77
1980-82
1988-90
J M M J S N J M M J S N J M M J S N
F A J A O D F A J A O D F A J A O D
Month

Figure 5.3

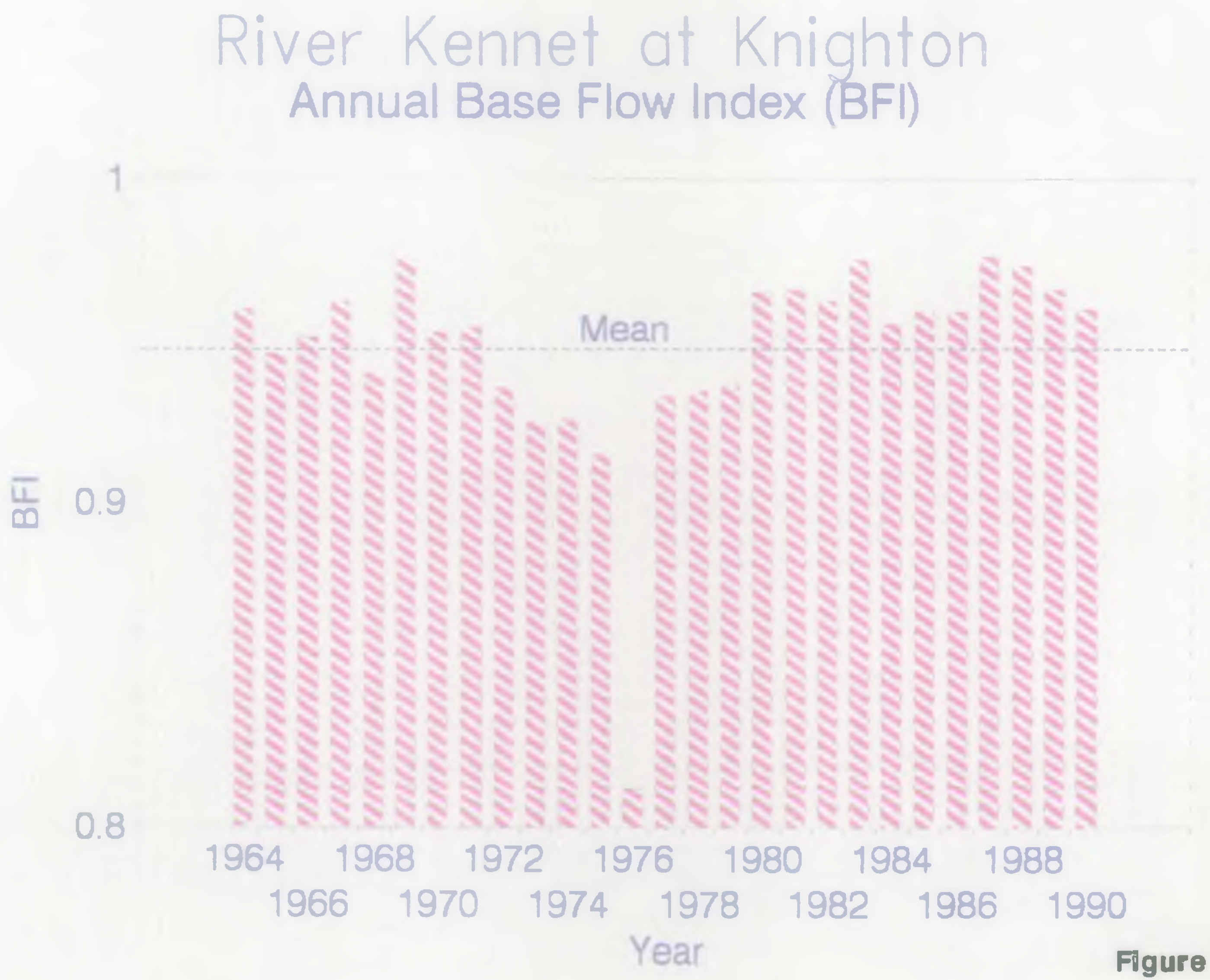
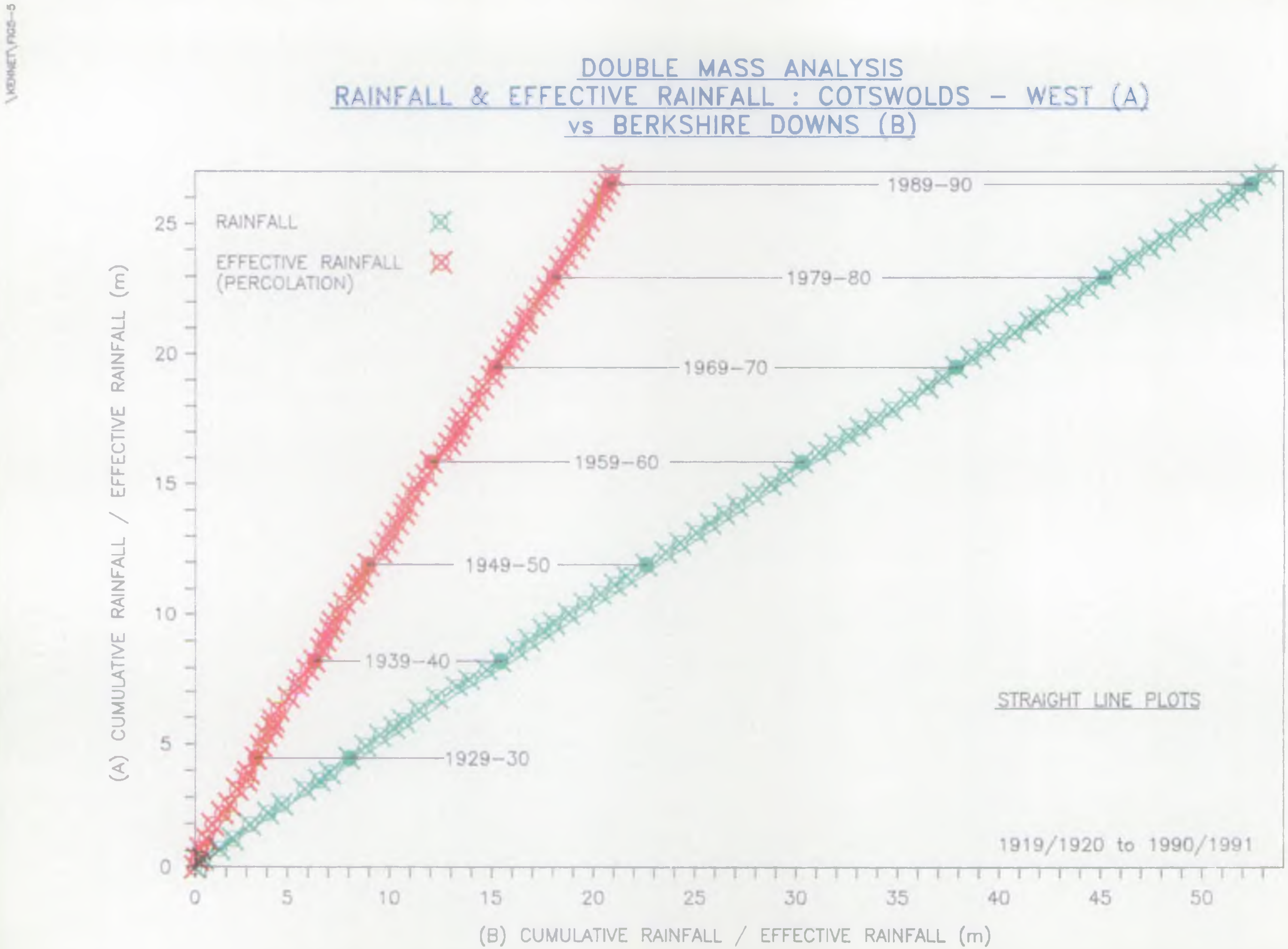

River Kennet at Knighton
Annual Base Flow Index (BFI)
1
0.9
0.8
BFI
Mean
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year

Figure 5.4



\KENNET\FIGS-5
DOUBLE MASS ANALYSIS
RAINFALL & EFFECTIVE RAINFALL : COTSWOLDS - WEST (A)
vs BERKSHIRE DOWNS (B)
RAINFALL
EFFECTIVE RAINFALL
(PERCOLATION)
1989-90
1979-80
1969-70
1959-60
1949-50
1939-40
1929-30
STRAIGHT LINE PLOTS
1919/1920 to 1990/1991
(A) CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)
(B) CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)
0
5
10
15
20
25
30
35
40
45
50

FIGURE 5.5

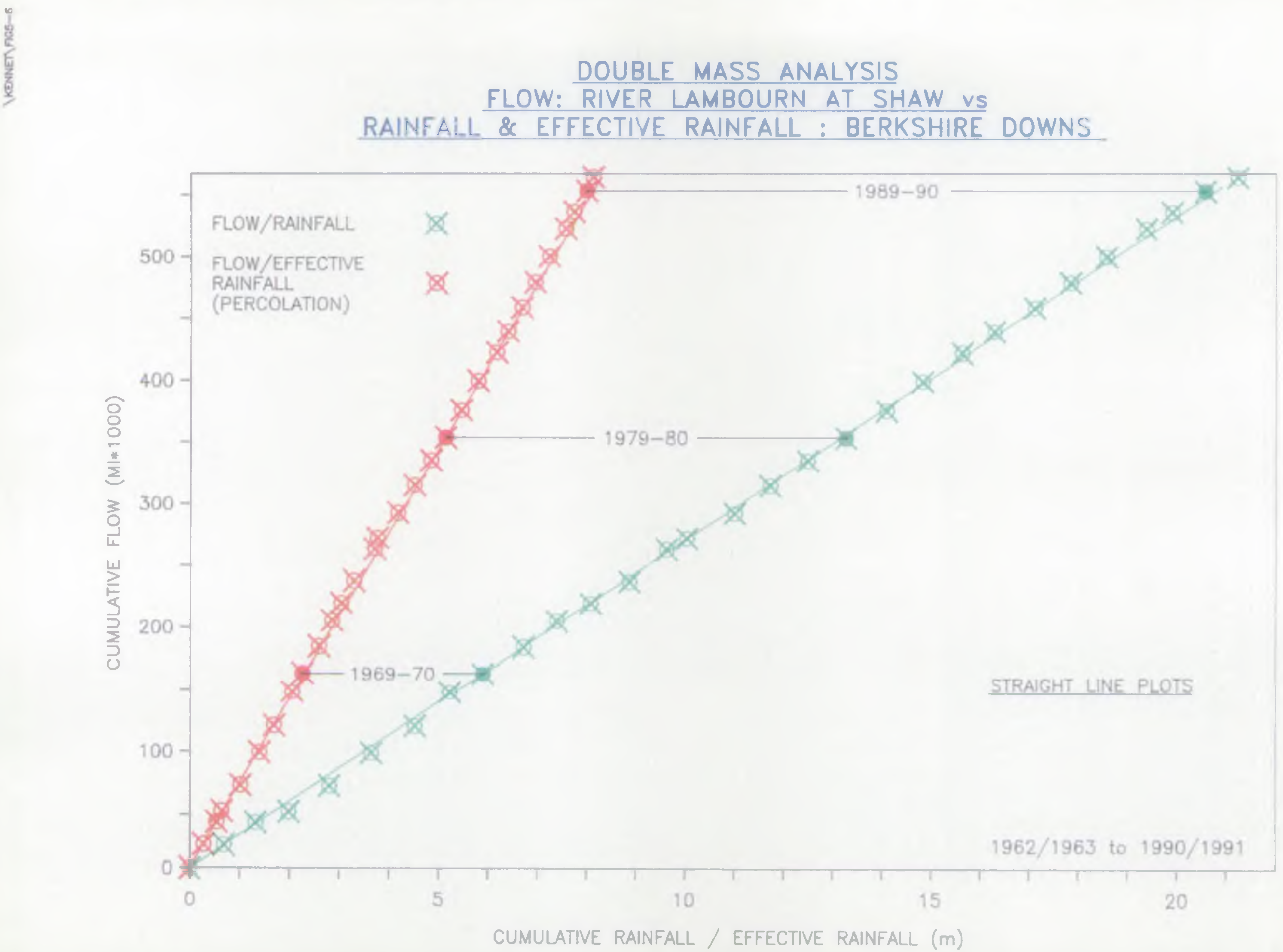

\KENNET\FIGS-6
DOUBLE MASS ANALYSIS
FLOW: RIVER LAMBOURN AT SHAW vs
RAINFALL & EFFECTIVE RAINFALL : BERKSHIRE DOWNS
FLOW/RAINFALL
FLOW/EFFECTIVE RAINFALL (PERCOLATION)
1989-90
1979-80
1969-70
STRAIGHT LINE PLOTS
1962/1963 to 1990/1991
CUMULATIVE FLOW (Ml*1000)
0
100
200
300
400
500
0
5
10
15
20
CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)

FIGURE 5.6

\KENNET\FIG5-7

DOUBLE MASS ANALYSIS
CUMULATIVE FLOW : RIVER KENNET AT KNIGHTON vs RIVER LAMBOURN AT SHAW

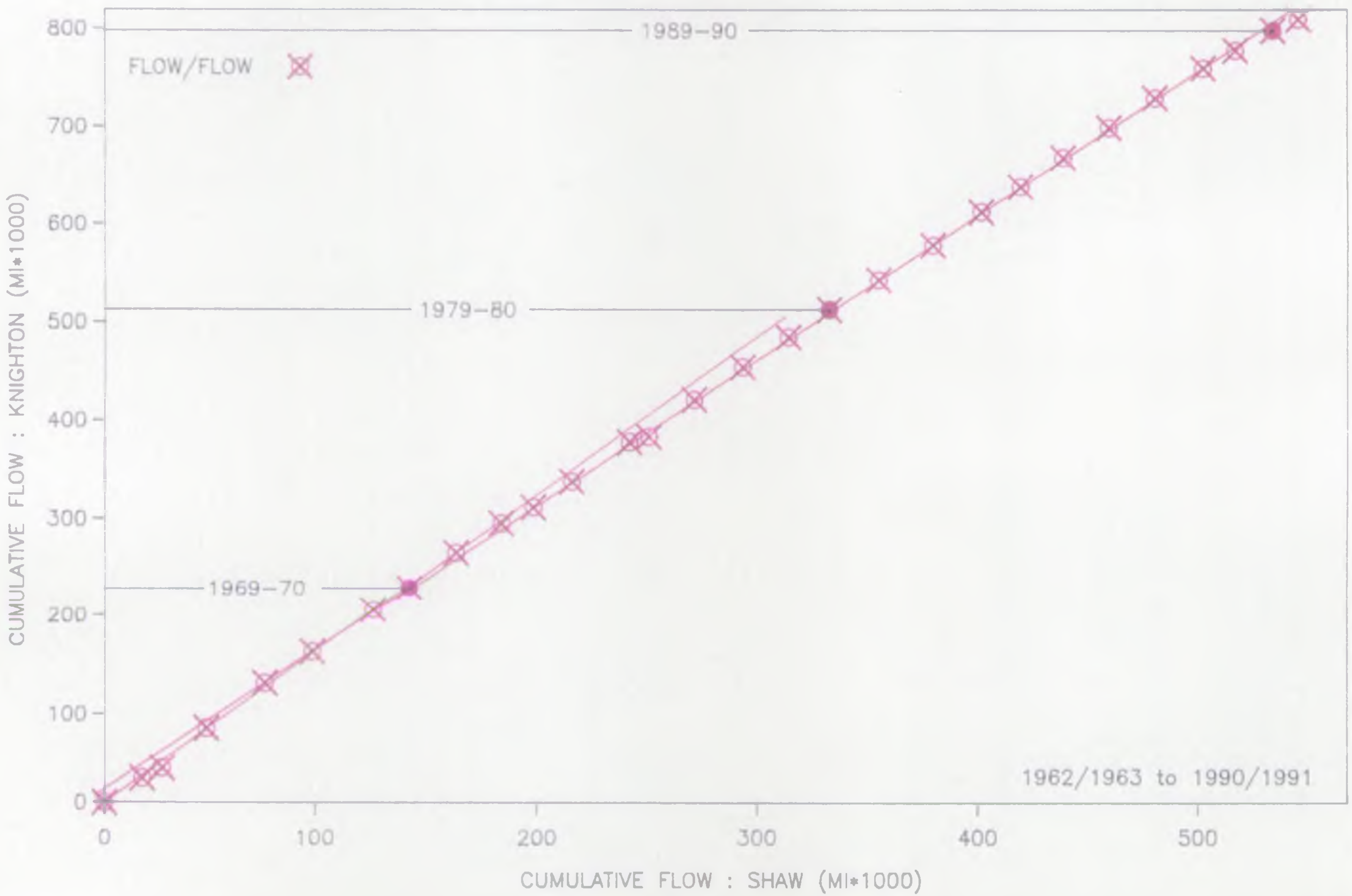
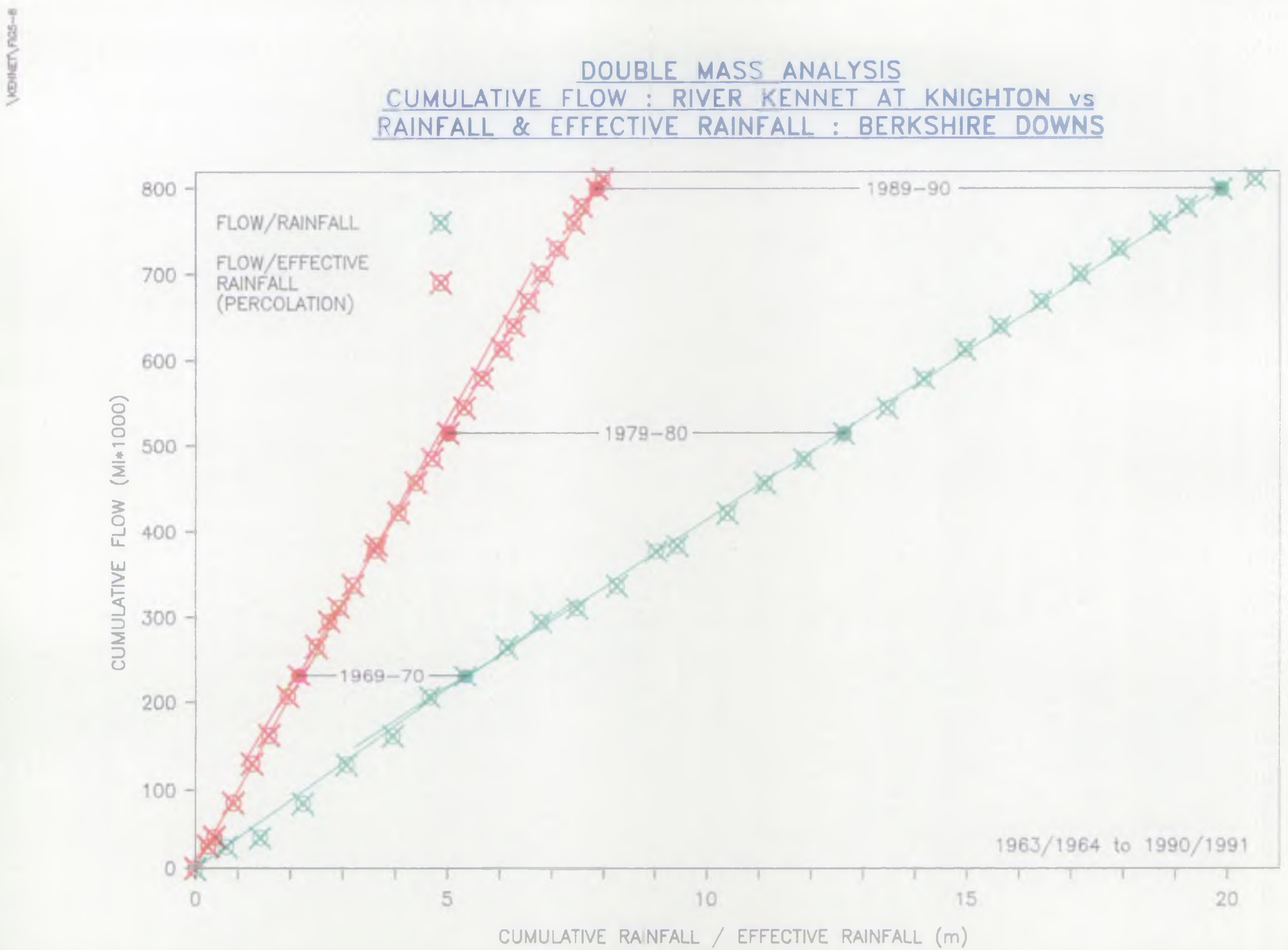


FIGURE 5.7



DOUBLE MASS ANALYSIS
CUMULATIVE FLOW : RIVER KENNET AT KNIGHTON vs
RAINFALL & EFFECTIVE RAINFALL : BERKSHIRE DOWNS
FLOW/RAINFALL
FLOW/EFFECTIVE RAINFALL (PERCOLATION)
1989-90
1979-80
1969-70
1963/1964 to 1990/1991
CUMULATIVE FLOW (Ml*1000)
CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)
0
100
200
300
400
500
600
700
800
0
5
10
15
20

FIGURE 5.8

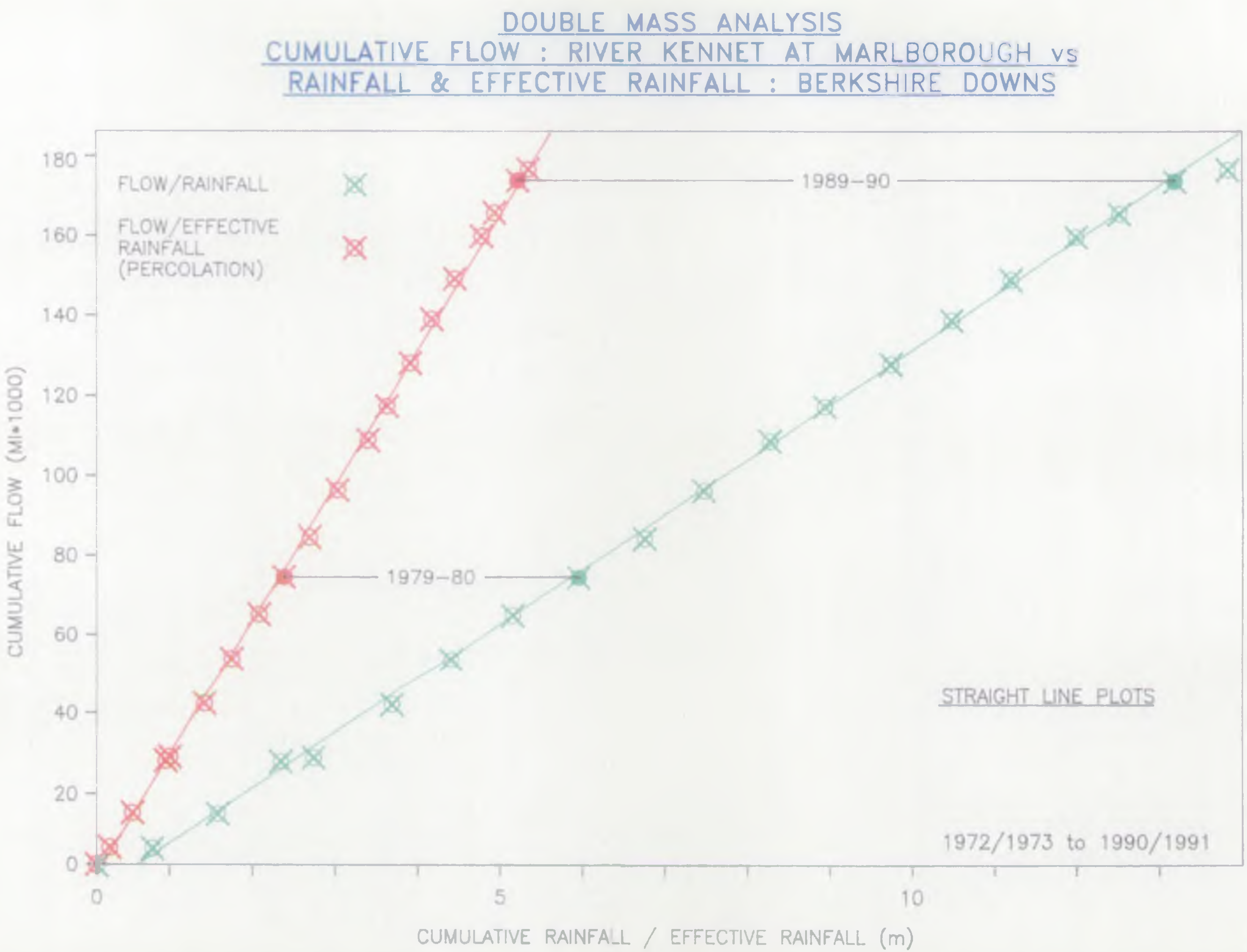
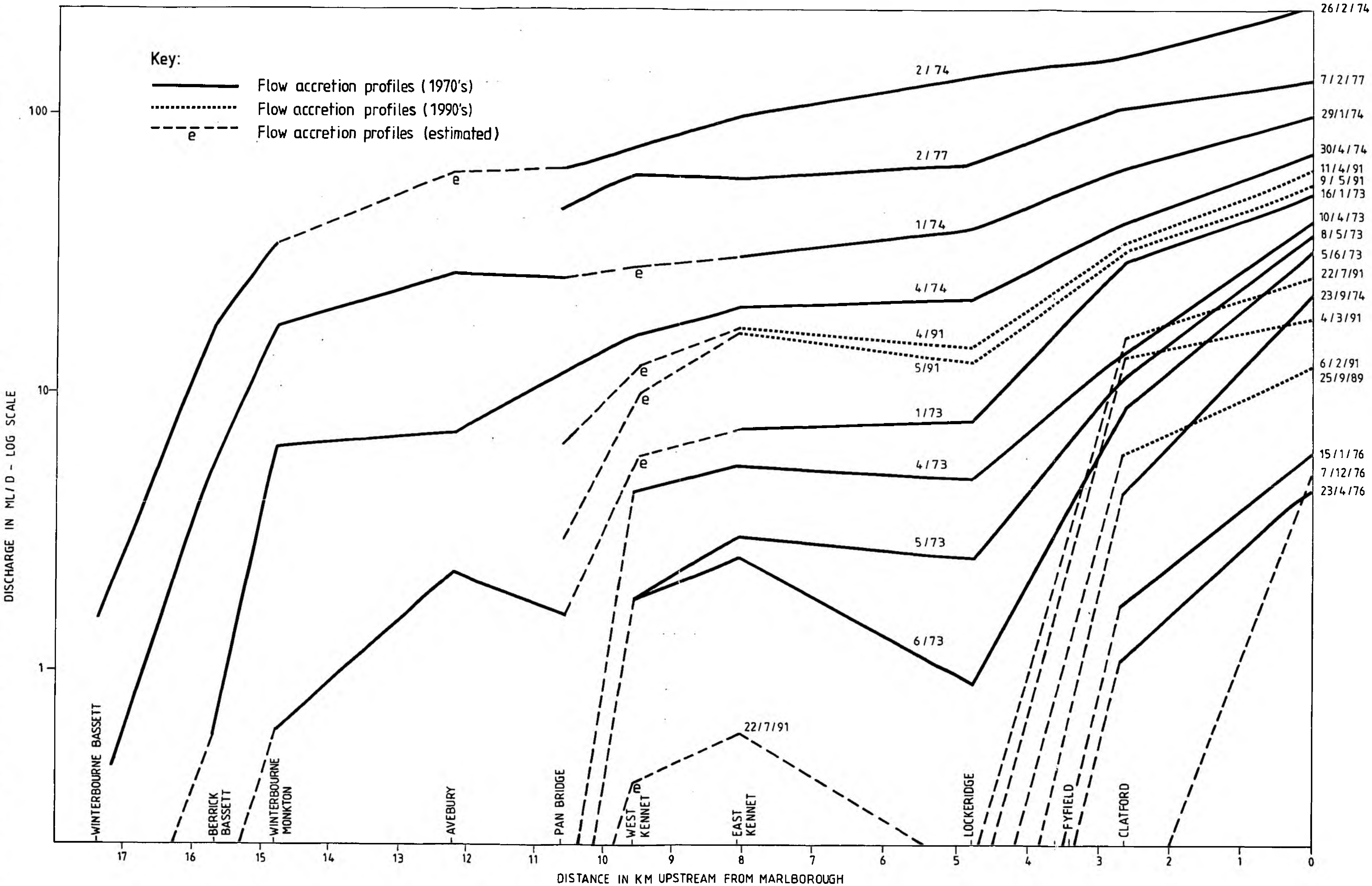

DOUBLE MASS ANALYSIS
CUMULATIVE FLOW : RIVER KENNET AT MARLBOROUGH vs
RAINFALL & EFFECTIVE RAINFALL : BERKSHIRE DOWNS
FLOW/RAINFALL
FLOW/EFFECTIVE RAINFALL (PERCOLATION)
1989–90
1979–80
STRAIGHT LINE PLOTS
1972/1973 to 1990/1991
CUMULATIVE FLOW (Ml*1000)
CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)
0
20
40
60
80
100
120
140
160
180
5
10

FIGURE 5.9



UPPER KENNET FLOW ACCRETION

Figure 5.10

6. WATER QUALITY

6.1 Introduction

The River Kennet drains the chalk catchment of the western Berkshire Downs. River flows are predominantly spring fed from chalk groundwater. Groundwater derived from the chalk tends to be clear, of even temperature and of good chemical quality.

6.2 Historical Perspective

There is very little historical data on the water quality in the River Kennet. The only relevant record concerned the formation of the Kennet Valley Fisheries Association in 1922. It is reported that the Association was set up in part to combat pollution which '... was a most serious threat in the early 1920s' and also to '... combat as far as possible the danger from the almost annual epizootics of furunculosis', a disease of fish.

6.3 Public Perception

The river has always appeared as milky in the Spring when the springs break, releasing groundwater with a high load of suspended chalk. For the rest of the year the natural groundwater baseflow tends to be 'gin clear'.

Several people have commented that the river now retains a degree of colouration throughout these traditionally clear periods. This has been reported most often on the reach from immediately above Marlborough to Littlecote.

Two specific pollution incidents were reported. The more serious incident concerned the spillage of 5000 litres of diesel to the river from a sewage pumping station in Marlborough in 1990. This caused significant damage at the time and put out of operation the fish farm at Mildenhall. The second incident concerned very high chalk sediment loadings related to installation of a pipeline across the river near Manton in 1985-6.

There have been a series of farm pollution incidents in the upper reaches of the Kennet but these have decreased in recent years in line with a change from dairy to arable farming and improvements in farm waste disposal practices.

Considerable concern has been expressed, particularly among river keepers, as to the increased rate of sediment build up in the river bed in recent years. The sediment is often associated with a black organic rich ooze and forms an unpleasant silty mud over the gravel river base. This smothers emergent weed growth and the loss of gravel means that trout are unable to build redds, adversely affecting the wild trout population. One theory, supported by experience from the Hampshire Avon catchment (Sawyer 1984), is that a major constituent of the organic material is decayed leaf matter. It is considered, in this context, that the number and size of trees overhanging the river has increased significantly over the last 10-20 years. The causes of this problem are considered further in Section 11 of this Report.

6.4 Factual Data

Characteristics of Chalk Stream Water Quality

Most chalk streams, including the Kennet, exhibit a characteristic water quality (see Table 6.1). As a result of the significant contribution of flows from the chalk groundwater aquifer, surface flows tend to have a relatively good and consistent chemical composition, with a relatively stable temperature regime.

Table 6.1 : Characteristic Seasonal Variation in Chalk Groundwater quality (all data in mg/l)

Data from the River Itchen - Hampshire

	Temp °C	Ph	Suspended solids	BOD	Ammoniacal nitrogen	Nitrate (as N)	Phosphate (as PO_4)	Chloride (Cl)
Mean 1980-1987	10.8	8.1	12.5	2.1	0.11	5.2	0.37	20.9
Jan-March	7.2	8.1	30.3	2.3	0.17	5.4	0.34	21.6
April-June	12.8	8.1	10.4	2.3	0.06	5.2	0.32	20.0
July-Sept	16.0	8.2	4.8	1.6	0.06	4.6	0.40	20.8
Oct-Dec	10.0	8.1	12.1	2.0	0.11	5.1	0.48	24.6

A number of seasonal variations characteristic of chalk streams can be observed from Table 6.1. Suspended solid concentrations are closely related to higher Winter and early Spring flows. Surface water temperature is related to the near constant groundwater temperature of around 10°C and, as such, is a much subdued reflection of air temperature. Increased water temperature in the Summer and consequent biological activity is likely to be responsible for the increased utilisation and observed reduction of both ammoniacal nitrogen and nitrates. The increases in chloride and phosphate concentrations in the Autumn are likely to result mainly from the reduction of flow, resulting in a lower dilution for the relatively constant input of treated sewage effluent.

The relatively high nutrient concentration of traditional chalk rivers, coupled with the constant flow regime with limited flood peaks, give rise to a highly productive aquatic environment.

Water Quality Classification

Specific sources of information regarding the water quality of the upper Kennet catchment are available from the NRA's routine and intermittent monitoring data. The NRA operates four routine water quality sampling sites in the catchment, viz Berwick Bassett (A), Marlborough gauging station (B), Mildenhall (C) and Stitchcombe Mill (D). Non routine water quality monitoring is also undertaken by the NRA in response to specific events such as pollution incidents. The majority of the routine sites are monitored monthly for a variety of parameters and the data are archived on computer back to 1975-76.

Attempts were made to access older, non computerised water quality information but were unsuccessful. However, we have reviewed data from the Upper Kennet Groundwater Survey undertaken by Thames Water Authority in 1974.

The upper part of the River Kennet from its source to Hungerford has an NWC river quality objective of 1A. This classification represents the highest category available and compliance is assessed against specific standards for dissolved oxygen, biochemical oxygen demand (BOD) and ammonia.

The routine sampling data indicate that the Upper Kennet complies with its 1A objective, although the sampling point for the statutory assessment is in Hungerford, some distance below the study area. Other sampling sites further up the catchment at Stitchcombe Mill and Marlborough gauging station also indicate that the water quality would have achieved its 1A classification regularly since 1977.

In general therefore, water quality in the upper Kennet may be considered to be of very high quality, acceptable for treatment to potable supply and capable of supporting game (trout) fisheries.

Specific Water Quality Parameters (i) Concentrations

Figures 6.2 to 6.5 show the mean annual concentration of selected water quality determinands through time as monitored at Marlborough gauging station and Stitchcombe Mill. These sites have the longest water quality records and can also be closely related to adjacent river flow gauging records, at Marlborough and Knighton respectively.

BOD levels in the river (Figure 6.2) indicate remarkable similarity between sites. Although the data are somewhat variable, a very modest upward trend, particularly over the last four years, is discernable.

Ammoniacal nitrogen (Figure 6.3) displays much less homogeneity between sites. Marlborough indicates considerable fluctuation through time, reaching a peak in 1989, before falling back in the two subsequent years. Stitchcombe Mill shows a significant reduction in average concentration between 1977 and 1983 followed by a steady increase until levels are, in 1991, almost equal to those of 1977.

Nitrate levels, measured as Total Oxidised Nitrogen or TON (Figure 6.4), display a modest but relatively consistent increase in concentration through time. This trend is very similar at both sites. The same trend has been observed in many other rivers throughout the UK and has been largely attributed to increased diffuse source inputs from arable farming. Both of these sites show an average TON concentration below that measured in the River Itchen (Table 6.1) over a similar time period.

Mean annual phosphate (PO_4) concentrations at Marlborough and Stitchcombe Mill, as shown in Figure 6.5, display a strong correlation. Stitchcombe Mill has some two to three times higher concentration than Marlborough, indicating a significant enrichment between the two sites. Of further interest is that, following a similar increase and decline in values through the 1980's at both sites, Marlborough is seen to return to the low pre-1980 levels, whereas Stitchcombe Mill displays a significant increase in mean phosphate concentration.

The levels of BOD, Ammoniacal Nitrogen, TON and phosphate found at both sites are not considered high however, nor are they likely to give rise to significant problems in the river environment.

Specific Water Quality Parameters (ii) Mass, Throughput or Loadings

A different method of analysing water quality is to combine data on concentration with mean flow data to assess the total mass throughput of any parameter. This has been done for Marlborough (Figure 4.6) and Stitchcombe Mill (Figure 4.7) using flow data from Marlborough and Knighton gauges respectively.

These plots indicate that there has been no overall increase in annual catchment throughput of any of the determinands at either Marlborough or Stitchcombe Mill over the period of record, although annual fluctuations for each determinand are observed. Ammonia (NH_4) and phosphate (PO_4) appear very consistent and unrelated to the flow rate. This indicates that the origin of these nutrients is largely from one or more consistent point sources and these are considered to be the effluent discharge from sewage treatment works. Fyfield STW probably accounts for much of the input above Marlborough and Marlborough STW contributes the majority of the increased loading to Stitchcombe Mill. The impact of STW inputs on water quality is considered further in Section 11.

The average annual contribution of BOD displays a declining trend. The BOD loading appears to have, at least in part, a damped response to flow. This indicates that BOD loadings are from both point sources (largely sewage treatment works) and from diffuse input to the catchment (e.g. runoff of organic material, in-stream flora and leaves).

Nitrate loadings appear to have a marked correlation with flow and this is consistent with a largely diffuse and catchment-wide input of nitrate, sourced largely from arable land. There does appear to be some increase in nitrate relative to flow over the data period but this is not a strong trend.

Temperature

The normal temperature regime of chalk streams tends to be one of marked uniformity throughout the year as most flow is derived from groundwater baseflow. Annual maxima are generally found during Summer when flows are low and ambient air temperature is high. Annual minima occur in response to the low ambient air temperature during Winter.

Table 6.2 gives the annual mean, minimum and maximum temperature values recorded at Marlborough since 1974. The mean annual temperature range from 8.9 to 11.1°C while the minimum and maximum values recorded over the period were 5 and 17°C respectively. There appears to be little discernable trend in the water temperature. The temperatures recorded are well within the tolerance limits for game fish. However, it has been reported that, in times of low flow and high air temperature, water temperature in the upstream reaches can rise sufficiently to kill fish. This is considered to be within largely ponded reaches upstream of Marlborough. It is noted that, prior to the last War, trout were removed from this reach in the Autumn of each year, for ponded storage near Ramsbury.

Table 6.2 : Annual mean, minimum and maximum temperatures for the River Kennet at Marlborough Gauging Station

Year	Min °C	Max °C	Mean °C
1974	6	14	10.0
1975	5	17	9.95
1976	6	14	9.9
1977	5	13	9.7
1978	5	13	9.65
1979	6	13	9.5
1980	7	13	9.8
1981	8	13.5	10.0
1982	8	14	10.5
1983	8	16	11.8
1984	6	17	10.6
1985	5	16	10.1
1986	6	12.2	8.9
1987	5	13	9.9
1988	8	15.8	11.1
1989	6.5	14	10.3
1990	7.5	17	10.9
1991	6.1	13.6	
			10.3

Suspended Solids

The useful data on suspended solids are limited to 12 years (between 1975 and 1991), recorded at Marlborough and plotted as Figure 6.8. The samples had a mean concentration of 9 mg/l and a total range of 1 to 340 mg/l. The mean annual concentration varies significantly over the period but there is no clear trend in the data. These data do not provide any evidence of an increase in sediment input to the river.

6.5 Water Quality : Summary and Conclusions

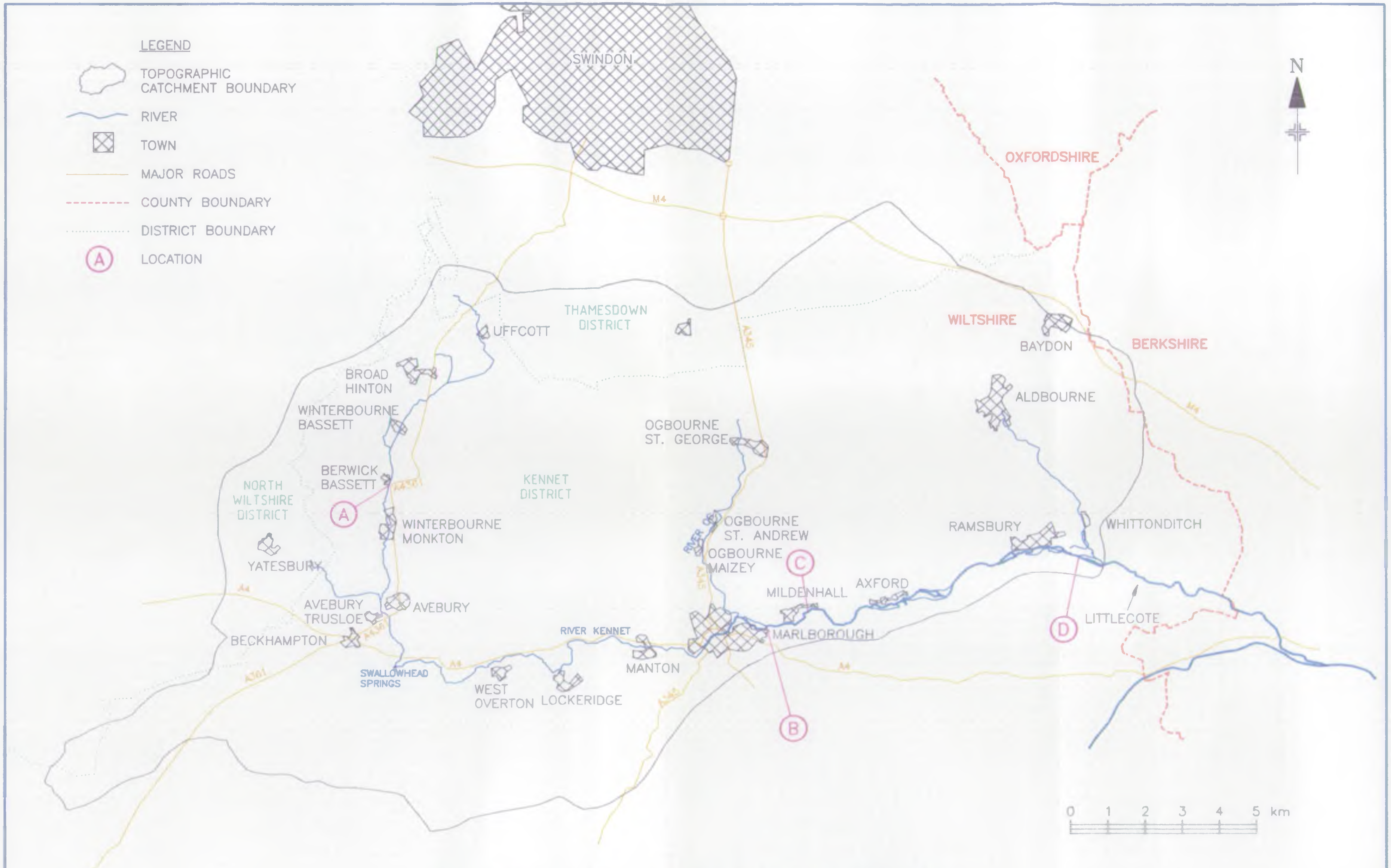
Water quality is not perceived to be a major issue in the catchment and the main concern reported was of increased siltation over the last few years. The data on suspended solids are limited but they do not indicate any increase in sediment loads over the period since 1974. Much of the surrounding river corridor comprises scrub and undeveloped pasture land and may act as a buffer to any increase in sediment runoff from the catchment. The reported increase in sediment load on the river bed may be due largely to the decrease in Winter flows over the last 2 to 3 years and consequent reduction in the river's ability to flush sediment. Previous over-dredging of the river, increasing the river cross section, will also have had an influence on the sedimentation characteristics. The black organic material within the river sediment may be sourced, in part, from STW discharges and the in-river vegetation. A further significant source for this matter may be fallen leaves from trees overhanging the river.

Water quality in the river is generally of a very high standard and the river easily passes its 1A river quality objectives.

The concentration of all the main determinands remained relatively consistent through the 16 year period of data collection. Correlation of loadings with flow indicates that phosphate and ammonia are input mainly from point sources, probably the two major sewage treatment works.

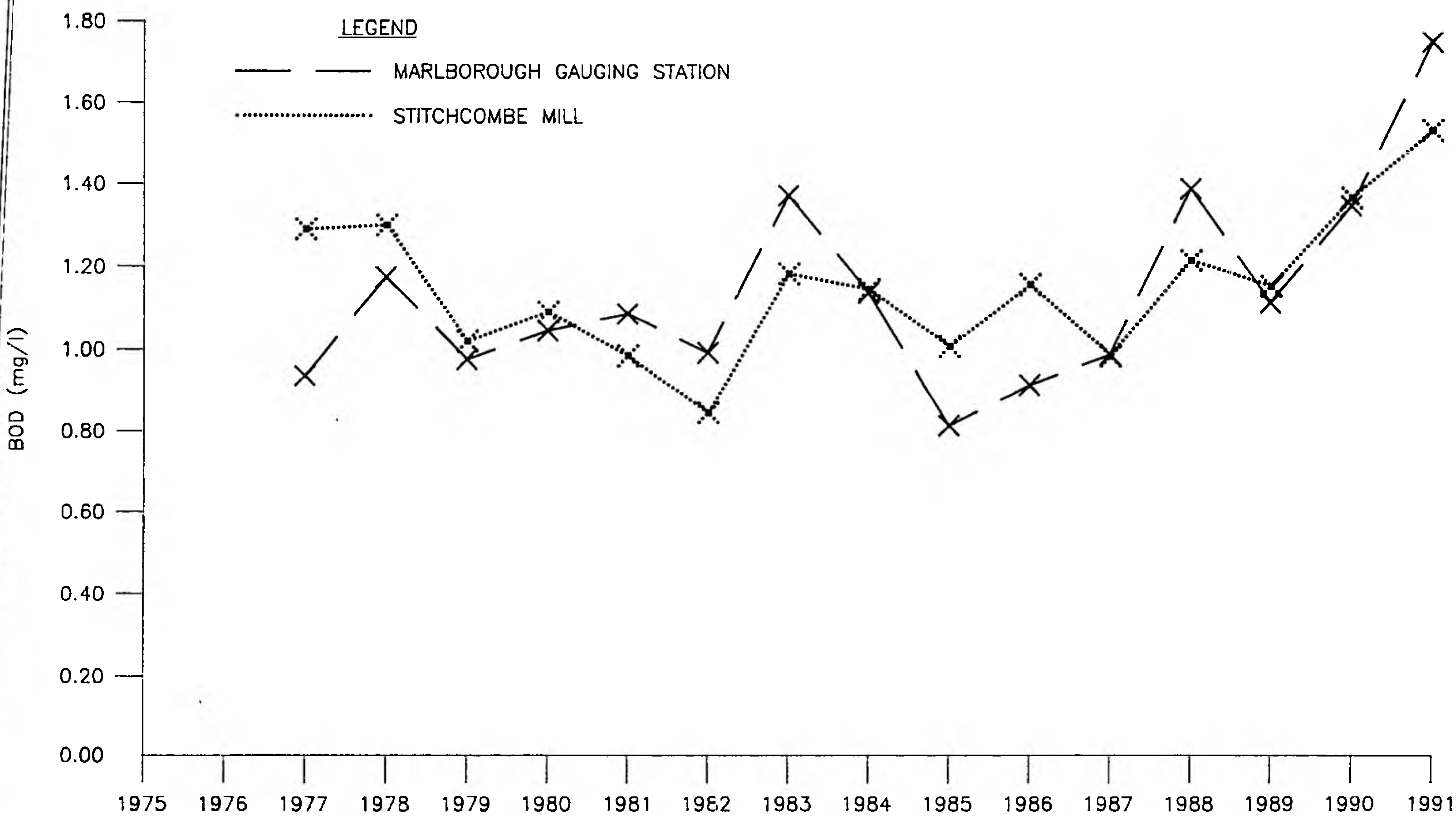
Levels of BOD appear to be controlled by both point and diffuse source inputs. Nitrate concentrations, in common with most other catchments in south east England, showed a gradual but steady increase over the period. Nitrate appears to be input mainly from diffuse sources probably related largely to agricultural development.

The causes of changes in water quality are considered further in Sections 11 and 12.



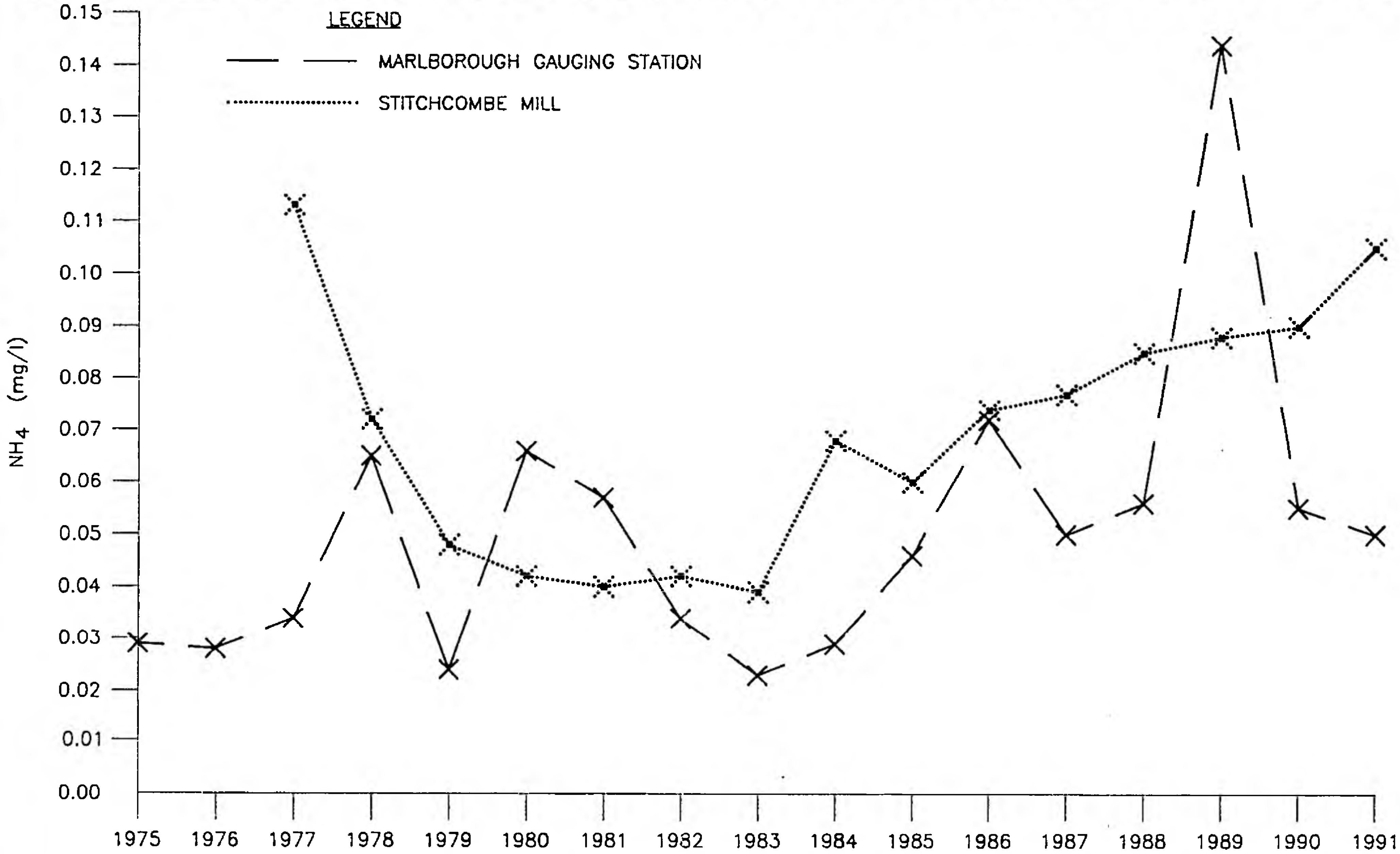
UPPER RIVER KENNET CATCHMENT
WATER QUALITY : LOCATION PLAN

FIGURE 6.1



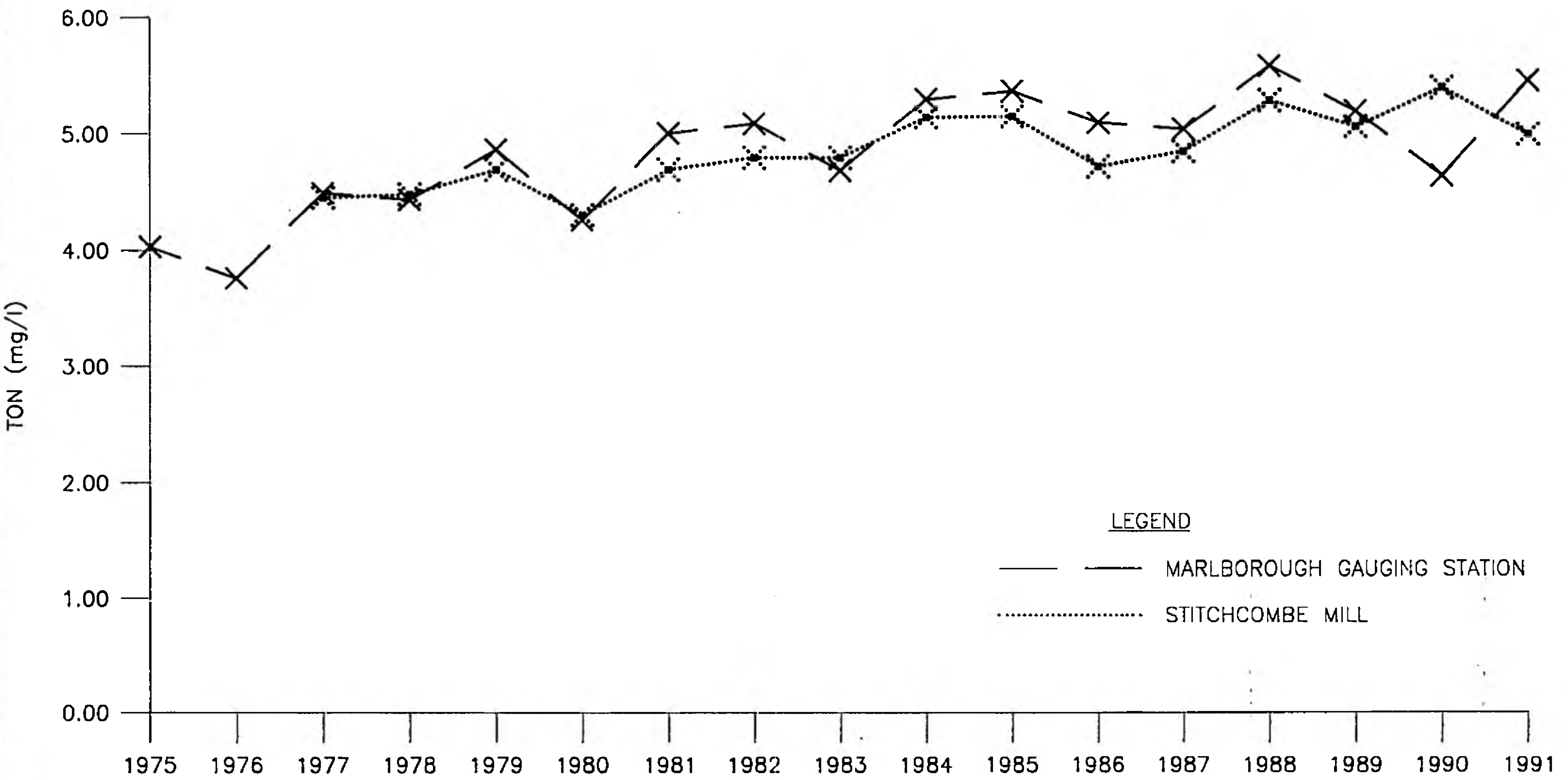
WATER QUALITY CHANGES THROUGH TIME FOR MARLBOROUGH GAUGING STATION & STITCHCOMBE MILL – RIVER KENNET (BOD LEVELS)

Figure 6.2

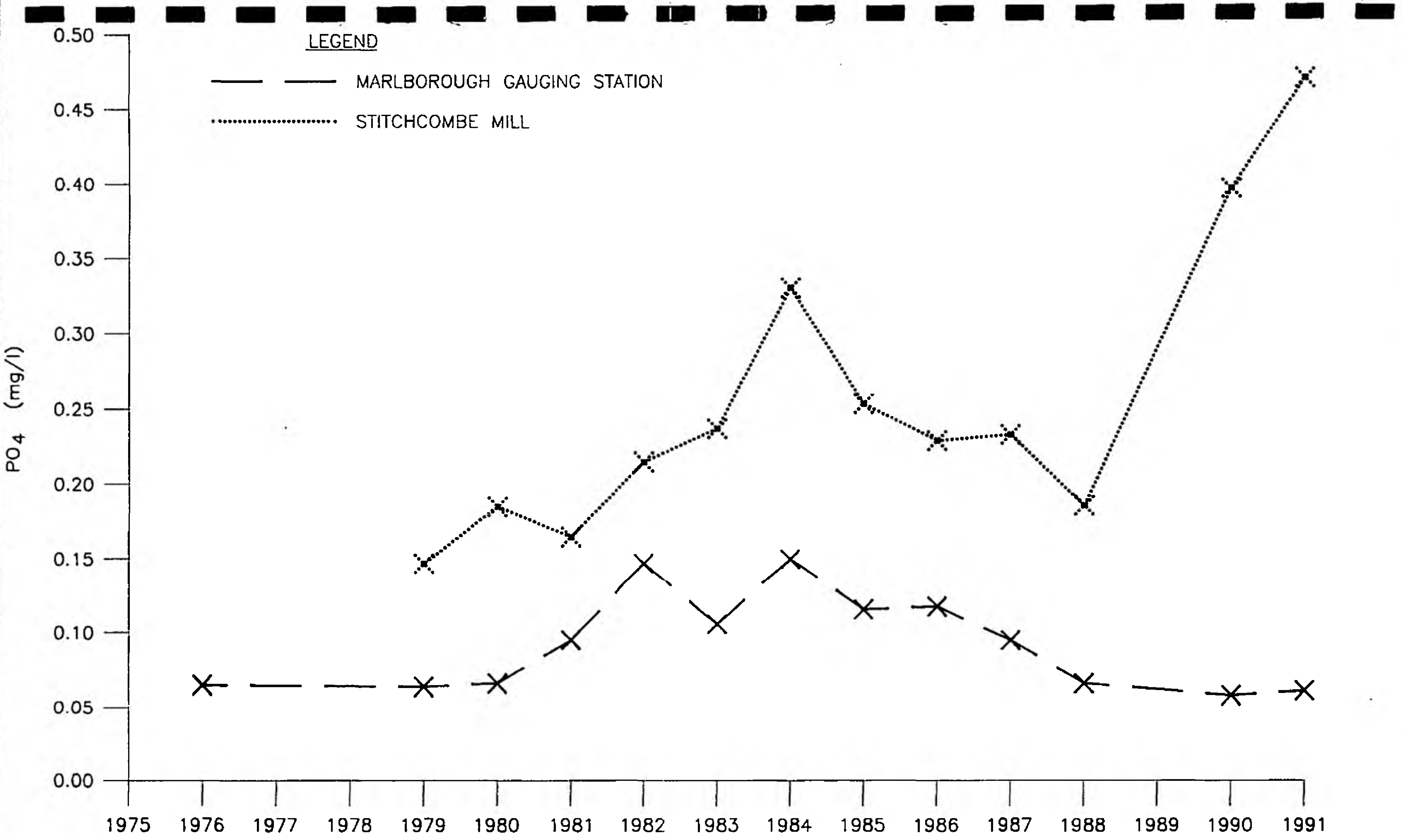


WATER QUALITY CHANGES THROUGH TIME FOR MARLBOROUGH GAUGING STATION & STITCHCOMBE MILL – RIVER KENNET (NH_4 LEVELS)

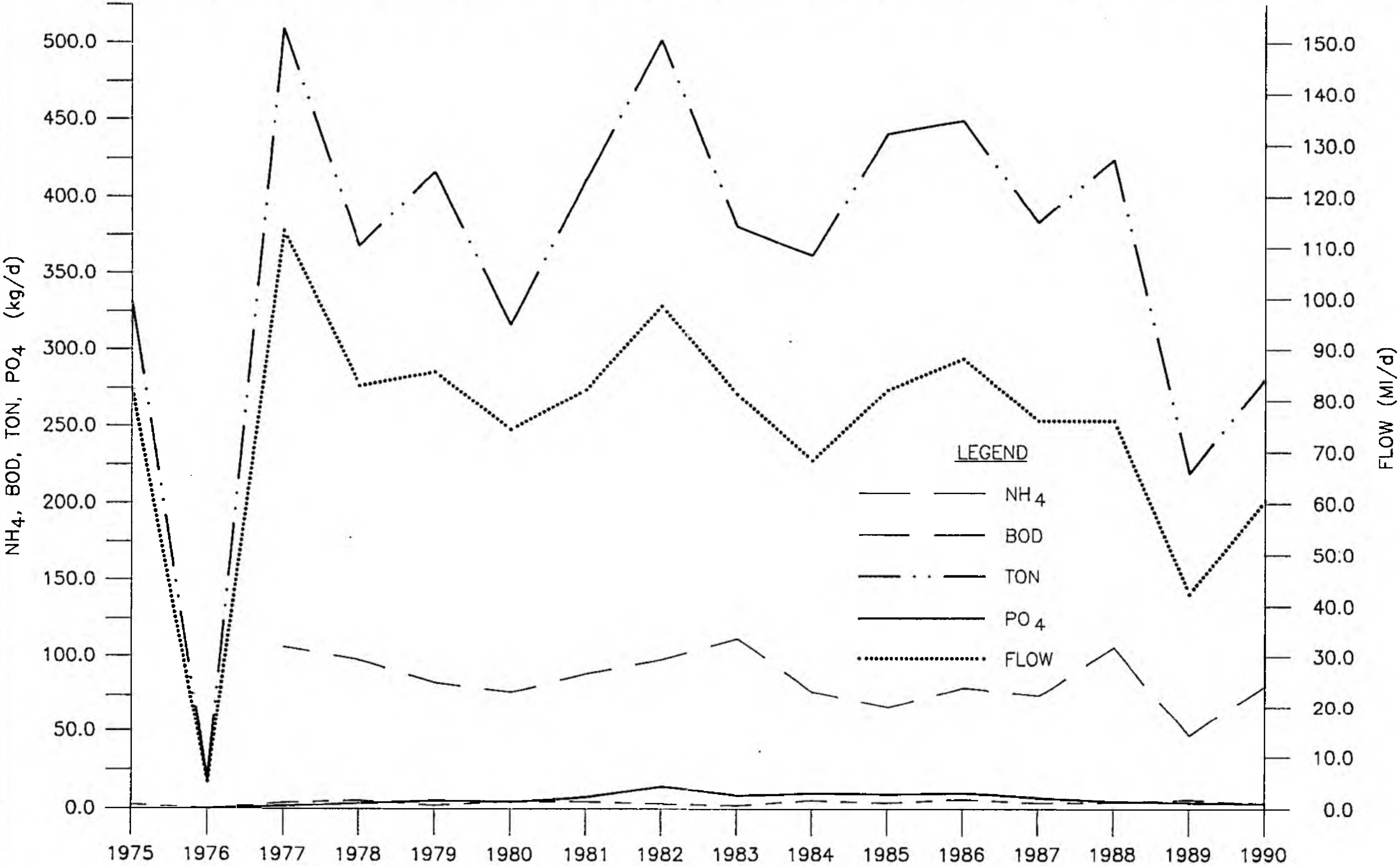
Figure 6.3



WATER QUALITY CHANGES THROUGH TIME FOR MARLBOROUGH GAUGING STATION & STITCHCOMBE MILL – RIVER KENNET (TON LEVELS) **Figure 6.4**

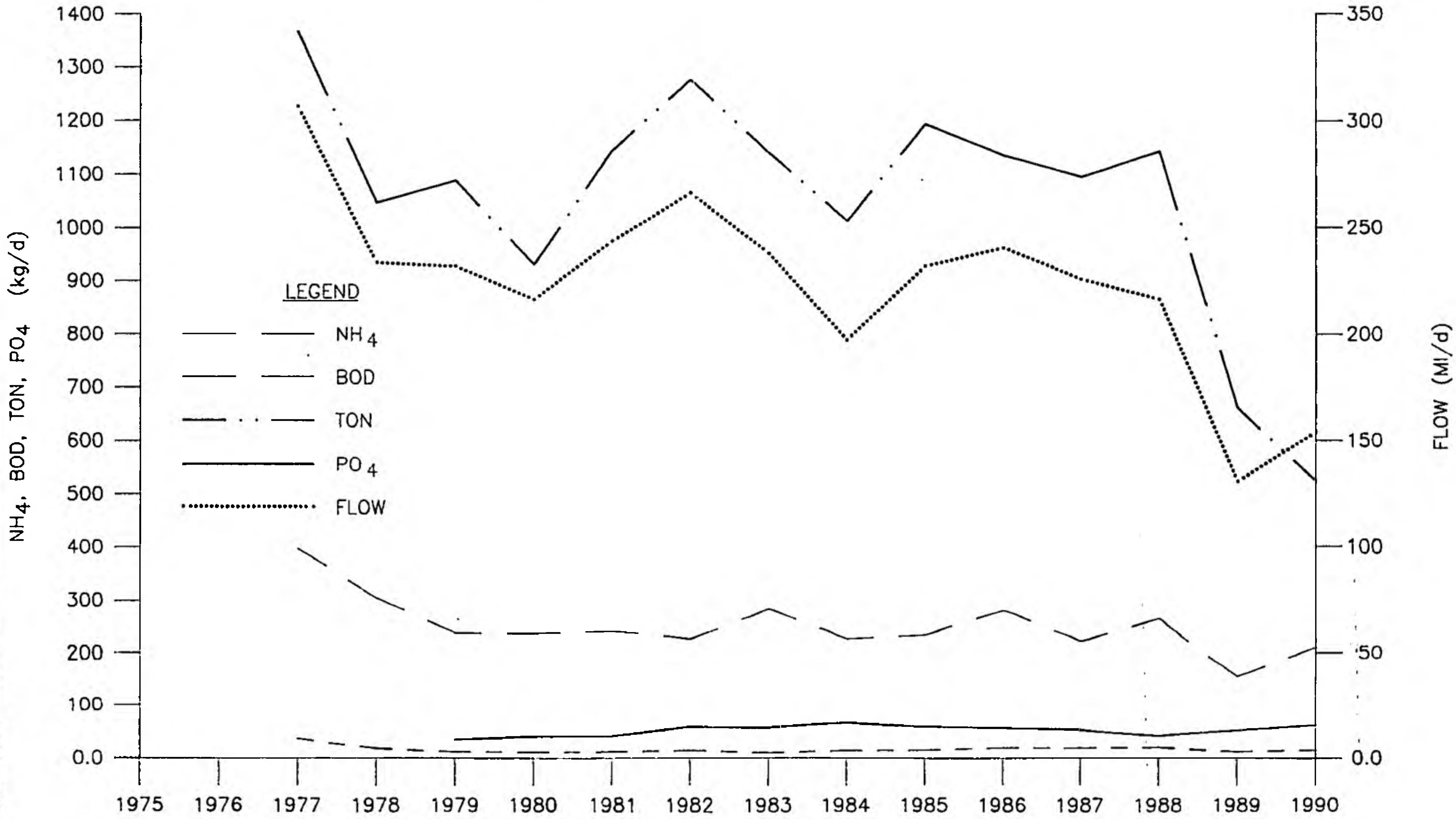


WATER QUALITY CHANGES THROUGH TIME FOR MARLBOROUGH GAUGING STATION & STITCHCOMBE MILL -- RIVER KENNET (PO_4 LEVELS) **Figure 6.5**



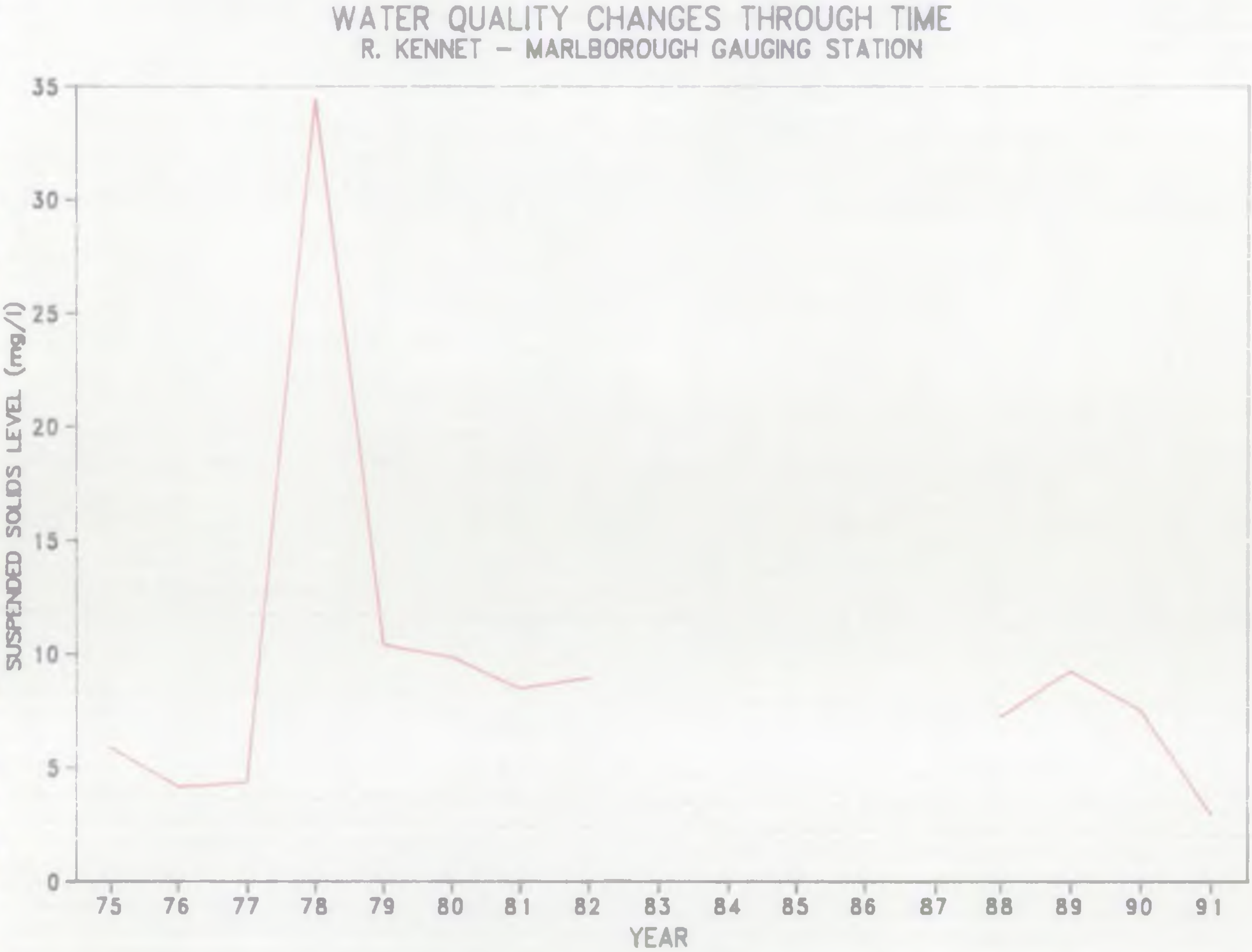
AVERAGE THROUGHPUT IN kg/d FOR SELECTED WATER QUALITY PARAMETERS AT MARLBOROUGH GAUGING STATION ON THE RIVER KENNET

Figure 6.6



AVERAGE THROUGHPUT IN kg/d FOR SELECTED WATER QUALITY PARAMETERS AT STITCHCOMBE MILL STATION ON THE RIVER KENNET

Figure 6.7



SUSPENDED SOLIDS DATA

FIGURE 6.8

7. FLORA AND FAUNA

7.1 Introduction

The River Kennet is a good example of a highly productive chalk river and supports a rich assemblage of plants and animals. The high baseflow nature of the river leads to a relatively consistent quality and flow environment. This is reflected in the abundance of submerged and emergent instream vegetation and the substantial and diverse populations of aquatic invertebrates and fish. However, the flora and fauna have, in many cases, a limited tolerance range outside the natural river conditions and changes within the river system are often reflected rapidly by changes in the biotic community.

In this document we have referred to instream vegetation by their common names as below:

Submerged Weed - This group roots in the stream base and exists mainly beneath the water surface although some produce flowers which are borne above the surface. Examples include *Potamogeton* (Pondweeds), *Ranunculus* (Water Crowfoots) and *Callitriche* (Water Starworts).

Emergent Weed - these plants have both leaves and stems growing up out of the water or along the water margins. Examples include *Veronica* (Brooklime).

Blanket Weed - this is a filamentous algae which forms an unsightly, scum-like floating mass. Also known as flannel weed, or cott.

Throughout this document the term "weed" has been used which, although not botanically correct, is the common generic term for all instream vegetation.

There is a classical annual cycle of floral development within a chalk stream as follows:-

- in early Spring the gravels are bare and the flow rate is high. This high flow rate encourages the growth of submerged instream vegetation such as *Ranunculus, Starwort* etc.

- in Summer the instream weeds have developed, resulting in reduced flow velocities and increased river levels. Silt builds up around the rooting systems and in low velocity points of the stream and emergent plants such as reeds, sedges and cresses start to encroach into the river upon silt these banks.

- in the Autumn the flow volumes are at a minimum but levels are largely maintained by the luxuriant submerged and emergent vegetation which both reduce channel cross-section and decrease flow velocity. Leaf material from overhanging trees contributes to the increased sediment content of the stream.

- in the Winter the decaying leaf matter and weed vegetation increases the BOD of the stream. The breaking of the springs, combined with reduced channel section, tends to result in a high velocity flushing flow which scours the channel, taking out the loose sediment and vegetable matter and clearing the gravels for the new cycle.

The fauna associated with the river are also closely aligned, in their breeding patterns and habitat, with this annual cycle.

The major issue examined in this Section is the extent to which this natural cycle has changed and the impact of these changes on the flora and fauna.

7.2 Historical Perspective

The main historical reference to this issue is 'The Passing of a River' written in 1947 by Colonel Maurice, which is already discussed in Section 5 with reference to surface flows. The paper makes a number of references to the floral and faunal quality of the river upstream of Marlborough in the late nineteenth century. He notes the presence of moorhen, dabchicks, kingfishers and discusses at some length the flora of the river.

In the late nineteenth century the trout of the river were considered as a useful food resource and the river upstream of Marlborough was netted each September. Colonel Maurice's family owned 3/4 mile of netting rights above and below the Hatch Pool (A). Large fish, up to 3 and 4 pounds, and one of 6 pounds were caught along this reach. Although dry fly-fishing had started in other southern rivers by the early nineteenth century (see, A Particular Lunn - One Hundred Glorious Years on the Test, by Mick Lunn) according to Colonel Maurice it did not reach the Kennet until the late nineteenth century. Colonel Maurice describes his fly fishing exploits up to, and in the years following the end of the First World War.

Colonel Maurice then left the Kennet area for 'many years' and returned, possibly in the mid to late 1930s. On returning he notes that the condition of the river had deteriorated and considers that the shrinkage of the river has been caused largely by abstraction. He describes the upper reaches of the river growing more and more stagnant, with blanket weed replacing more normal river weeds. He also notes a large loss of fish at the Mill Pool (B) and relates this to the total loss of 'river weed' and replacement with blanket weed. The description of reduced river flows accompanied by a change in the weed life and resulting in a loss of fish habitat is very similar to the descriptions given to the current state of the river.

As noted in Section 6.2 above, the Kennet Valley Fisheries Association was formed in 1922, largely to combat the issue of water quality in the river.

Mr Philpott of Lockeridge used to act as a part-time keeper on the river in the 1920s and 30s. He remembers that the river was still netted each Autumn, as recounted by Colonel Maurice, downstream to Marlborough. This was done, in part, to save the fish from the Autumn recession in river flows, and the trout were stored in a pond near Knighton for re-stocking in the Spring.

7.3 Public Perception

The main issues on the floral and faunal character of the river recorded by the public are as follows:-

- loss of fauna, particularly bird life, in the upper reaches
- loss of submerged river weed (*Ranunculus, Starwort* etc) and replacement by blanket weed
- increased encroachment of emergent vegetation
- increased silt and organic material
- deterioration in trout habitat.

There has been considerable concern expressed with regard to the decline in the variety and number of faunal species inhabiting the upper reaches of the river. In particular Mr Russell of the British Trust for Ornithology has collected 20 years of records on the 7 kilometre stretch from Manton to East

Kennett (C). The data show a decline in the diversity of bird life over the last seven years including:

- Absence of sedge and reed warblers since 1986 - these birds require marshy conditions.

- Absence of snipe and redshank since 1979.

- Reduction in the breeding success of mute swans from 4 pairs in 1984, progressively until there were no breeding pairs in 1990.

Mrs Robbins, a resident of East Kennett (C) over the last 20 years, reports that there are no longer herons, kingfishers, swans and coots along her reach of the river.

It is also reported that wild brown trout have been absent from the upper reaches since 1986 when the river was dredged along this section and, at present, there are thought to be no native fish upstream of Marlborough. *Ranunculus* is almost absent and has, for example, largely disappeared immediately below Marlborough. Submerged weeds are limited to patches of *Starwort* in the reaches that pass through Marlborough College.

John Hounslow, the river keeper at the Crown Estate downstream of Marlborough (D), reports a major change in weed growth along his reach as below:

- 8 to 9 years ago (1982-3) weed growth was a major problem with regard to flood defence.

- In 1984-5 he had to undertake a number of heavy weed cuts to control growth. In 1990 he did two light cuts and in 1991 he did not cut the weed at all. Mr Hounslow used to believe that loss of weed in his reach was directly related to the effluent discharge from Marlborough. This was because, above Marlborough, say between East Kennett (C) and West Kennett (E), when flows increase in the Spring the river weed also returns, whereas below Marlborough the weed is gradually disappearing. However, following some in-river works to reduce the river section and increase flow velocity, the reach immediately downstream of the Marlborough discharge has now started to develop a healthy submerged weed growth whereas the problems on the downstream reaches continue to develop.

- In the Spring of 1991 the river above Marlborough had a good, clean gravel base whereas below Marlborough there was a widespread cover of silt and decaying organic matter.

- Emergent plants such as *Myosotis* (water forget-me-not) have been encroaching on the stream increasingly over the last few years.

- Problems with blanket weed on the river in the Crown Estate last year (1991) lasted from February to June.

- The River Og also used to be choked with weeds and was used as a spawning area for trout. Small tributaries are often used by trout in this way. Mr Hounslow believes that there is insufficient flow for the fish to continue to do this in the Og.

7.4 *Factual Data*

This sub-section discusses the analysis of factual data on both the range and density of invertebrate life, fish stocking records and weed development. Further information on the floral and faunal species typically associated with chalk streams is given in Appendix B.

Aquatic Weeds

Chalk streams with their stable, nutrient rich flow and temperature regimes, provide ideal conditions for the growth of aquatic plants. Characteristically these streams are dominated by dense growths of the submerged perennial *Ranunculus* (water crowfoot), particularly in the swifter flowing areas; other submerged and emergent aquatic plants common in chalk streams, all exploiting slightly differing niches of flow velocity, light availability and substrate composition, include *Apium nodiflorum* (Fools water cress), *Callitriche* (starwort), *Rorippa* (watercress), *Veronica* (brooklime) and *Potamogeton* (pondweed).

Typical seasonal growth patterns of submerged weed such as *Ranunculus* show that growth begins in the Autumn or early Winter, although it is late Winter to early Spring before significant increases in biomass are generally observed. Growth during the Spring is typically rapid and maximum biomass is reached by Summer. With the advent of flowering between May and July, much of the plant's growth effort is diverted to reproduction. Shortly after flowering the plants wither and die. Increased flows in the Autumn and Winter will tend to rip out and remove this decaying vegetation.

Traditionally, intensive management has been required in order to control these submerged weed growths in the Kennet catchment. Dense growths are capable of severely impeding flows and may increase the risk of localised flooding. Dense weed growth may also make angling, particularly fly fishing, impossible.

As reported in Section 7.3 above, there has been a progressive decrease in the growth of river weed, and *Ranunculus* in particular, and replacement with blanket weed. The issue of progressive weed loss is not unique to the Kennet catchment. On the contrary, many of the river catchments in south eastern England, and particularly those that are fed largely by groundwater baseflow, have been affected by loss of submerged weeds. Among the catchments affected are both the Wiltshire and Hampshire Avons, the Test and Itchen, Wylie, Windrush, Coln and Cherwell. Comparative symptoms are also noted by Colonel Maurice for the Upper Kennet from 1946, as noted in Section 7.2.

We discussed the whole issue of weed loss with the Aquatic Weed Research Unit at Reading University and the following points were made :

- The growth of submerged weed is dependent largely on its photosynthetic ability. This ability is determined largely by flow velocity across the weed, controlling the dissolved oxygen available to it and the related issue of epiphytic (algal) growth on the weed. It has been found that reduced flow velocities will reduce photosynthetic capability by 95 per cent.

- Water quality can control weed growth. Submerged weeds receive sufficient nutrient for growth from very low nutrient waters. Algae require a nutrient loading of 15-20 ug/l, but this is still well below the concentrations in virtually all chalk rivers and streams. Above this lower limit, the balance between weed and diatom growth appears to be related principally to flow velocity and oxygen concentration. There will clearly also be an upper tolerance limit for weed growth but it is not considered that water quality in the Kennet approaches this limit.

- Root clogging, for example by silt, organic material and algae, restricts weed growth. Weed will also die in warm shallow water.

- Emergent and encroaching weeds will tend to grow in preference to submerged weeds if (i) the water levels are reduced, (ii) flow velocity is reduced, (iii) silt substrate is increased and (iv) the frequency of flood flows is reduced.

- Swans in particular, but also other wildfowl, are considered, particularly by river keepers, to have a significant detrimental effect on weed growth. It is considered that swans, which when feeding rip weeds from the substrate, may be detrimental to the river where weed is already sparse. It is also relevant that, due to lower river levels, it has become easier for the swans to reach and take young fresh shoots whereas in normal conditions they would only reach the mature plant. Under normal conditions the detrimental effects of swans are considered a lot less severe.

- It is not considered that the herbicides, pesticides and fungicides applied to arable crops will have any detrimental impact on aquatic weed.

- Weed requires sunlight for growth but shading is not found to be a reliable method of restricting weed growth.

- Submerged weed will re-colonise rapidly as long as (i) the instream conditions are suitable and (ii) either roots are present or there is a healthy flowering growth upstream.

In summary, it appears that the primary factor controlling weed growth is flow velocity. If flow velocity is lost (i) conditions are more favourable for both emergent weeds and blanket weed and (ii) silt will tend to drop out of suspension smothering the roots and causing further weed loss. Loss of weed leads to reduced river levels (as noted in Section 12 below) and, under these conditions, the young weed shoots are more vulnerable to wildfowl. It is relevant to note, in this regard, that river management practices to increase flow velocity undertaken on the Crown Estate downstream of Marlborough, have resulted in a marked improvement in the growth of submerged vegetation when compared to adjacent reaches. These experiments are also discussed further in Section 12.

A study was undertaken 10 years ago considering weed growth in the River Lambourn catchment (Ham et al 1981) which is immediately to the east of the Aldbourne, flowing into the Kennet about 20 km east of Knighton. The study showed a close positive correlation between the growth of *Ranunculus* between March and June of any year and the mean daily flow over this period.

Invertebrate Taxa

The presence or absence of particular invertebrate taxa can be used to assess the ability of a water course to provide adequate habitat. A formal method of assessment is to produce a BMWP (Biological Monitoring Working Party) score for the river. This method allocates a value of between 1 and 10 to each taxon found, with higher scores given to taxa which are more sensitive to changes in water quality, especially organic pollution. Another measure is the ASPT (Average Score per Taxa) which, as the name suggests, indicates the mean sensitivity of the taxa present in terms of their BMWP score.

BMWP's and ASPT's have been monitored at Newbury, 20km downstream of Knighton gauge, since 1978 and at Stitchcombe Mill downstream of Marlborough, over the last four years. These data, smoothed by plotting 3 year moving averages, are on Figure 7.2.

In general, the predicted BMWP scores indicate the nature of the habitat given the absence of pollution. However, (i) BMWP scores may show an increase if the sample covers a mosaic of habitats including still-water zones and (ii) high scores need not always imply flowing water conditions throughout. The ASPT (Average Score Per Taxa) is a more sensitive measure of clean-water fauna.

The diversity in the river at Newbury is particularly good and no overall trends can be detected from 1978 to the present, though there are shorter term fluctuations in the diversity scores. It is difficult to draw conclusions from the short record at Stitchcombe Mill although the increase in BMWP score and decrease in ASPT may reflect lower flows and an increase in a still-water fauna. A review of the taxa registered over this time period reveals a general decline in the abundance of families normally associated with faster flow conditions and a slight increase in the slow/still water community. The families of the latter group, the *Gerridae* and the *Hydrophilidae* (pond skaters and water beetles) make their first recorded appearance in the summer of 1991. Conditions of reduced flow are therefore indicated at this site though a longer time sequence would be needed to confirm an overall trend.

Further information on the type of fauna typically associated with chalk stream habitats is given in Appendix B.

Fish Surveys

The NRA undertook a comprehensive fish survey of the Kennet catchment in 1988-89 including 3 sites within the study area, at Manton, Marlborough and Ramsbury. All three sites supported relatively good fish biomass concentrations, although Manton displayed an under representation of younger age classes despite the appearance of a healthy aquatic environment. A further survey was carried out in October 1990 to monitor any changes from the 1989 survey with particular respect to low flow problems. No significant changes had occurred with one site having remained reasonable, one remained poor and one remained good.

The river is heavily stocked throughout much of its length and it is difficult to draw any firm conclusions from these surveys.

7.5 Summary and Conclusions

The Upper Kennet catchment has a typical chalk stream ecology, i.e. healthy and diverse, supported by a high nutrient content and a relatively stable flow and quality regime. One of the effects of this stability is that the ecology is relatively sensitive to change. There is a widespread public concern that the nature and diversity of the fauna and flora has changed, with a gradual decline over the last 5 to 6 years accelerating over the last 2 to 3.

One particular concern relates to the reduction in the diversity of birdlife in the upper reaches of the river between Marlborough and Swallowhead Springs. This reduction would appear to correlate well with both reduced period of flow and the associated loss of in-stream vegetation over this period.

Concerns were reported by Colonel Maurice in 1946 as to the loss of fishing habitat over the preceding 20 to 30 years in this same upstream reach. This reach of the river apparently provided habitat for trout in the pre-war period and was also keepered up until the Second World War. However, the fish were removed at the end of the summer, at least in the 1920's and 30's, and stored in a pond near Knighton to be restocked when flows recovered in the Winter.

The major concern in the river is the reduction in the growth and presence of submerged plants. This is illustrated by the reduction in the necessity for weed cutting in one reach from 3 to 4 cuts in 1984-5 until last year (1991) when no weed cuts were necessary.

The growth of weed appears to be related, primarily, to the in-stream flow velocity, particularly in the period March to June. The reduction in flow velocity also leads to the increased deposition of silt and mud, and the early encroachment of emergent and bank vegetation. Further reductions in velocity, and possibly increase in temperature, may lead to the development of blanket weed. If the Winter and early Spring flood fails then the stream bed is not flushed of the build up of silt and organic matter. This reduces further the potential for growth of submerged vegetation during the Spring period. This process of reduced flow velocity leading ultimately to the dominance of blanket weed was also reported by Colonel Maurice in 1947.

There is no evidence that water quality is a significant control on the floral changes observed.

STAGE TWO - POTENTIAL FACTORS IN CAUSING CHANGE

STAGE TWO - POTENTIAL FACTORS IN CAUSING CHANGE

8. INTRODUCTION

Stage Two of the study considers each of the main factors impacting upon the character of the catchment and examines the likely impact of each factor in relation to the changes identified in Stage One. A separate section considers the cumulative effect of these factors and summarises our current understanding of the cause and effect relationships operating within the catchment. Two further sections consider, in outline only, (i) the potential remedial measures and (ii) the further works recommended to either investigate or carry out these measures.

9. METEOROLOGY

9.1 General

Meteorology is the most important factor governing variations in river flow within a natural river system. Clearly rainfall is the primary input to the system, although it is the effective rainfall which is a more direct measure of the available water resources.

Effective rainfall is defined as the rainfall minus the losses from evapotranspiration. Effective rainfall results in either surface runoff or recharge ('percolation') to the groundwater aquifer. In the Kennet, as in most chalk catchments, the large majority results in recharge. The effective rainfall to the Kennet catchment is therefore considered to represent the 'percolation' and estimates of percolation for the Berkshire Downs are derived by NRA Thames from their regional soil moisture balance model.

This section considers the historical record for both rainfall and percolation and the impact of variations in this record upon surface flows in the Kennet catchment.

9.2 Meteorology and the Kennet Catchment

The main meteorological features of a typical year for the Kennet catchment are considered below.

Autumn

The main period of recharge generally starts in October-November when the Summer soil moisture deficit has diminished or eliminated. Surface flows and groundwater levels are at a minimum at this time. As recharge continues groundwater levels rise and the surface flows respond.

Winter

A feature of this catchment is the 'breaking of the springs' in December-January of a typical year, when groundwater levels are sufficiently high to cause major outflows from the main spring sources in the upper part of the river from Marlborough up to and including Swallowhead Springs.

Spring

Groundwater levels and surface flows generally reach a peak around March, after which increased evapotranspiration reduces recharge.

Summer

Typically there is then very little recharge of the aquifer until the following Autumn and there is, accordingly, a natural recession in both groundwater level and surface flow.

If there is an extended period of reduced rainfall over the Winter period this will result in a muted groundwater response and reduced spring flows in the following Summer, and continued groundwater baseflow may drain the aquifer to below the normal minimum level. In the Winter of 1975-76, for example, very little recharge occurred and Summer flows and groundwater levels were, accordingly either at or near to the lowest on record. The effective rainfall the following Winter was greater than average however and baseflows had recovered by the following Summer.

The situation in the current drought period is somewhat different. Following a high rainfall in the Winter of 1988-89 there followed a Summer of low rainfall, leading to low flows in the following Summer. The Summer of 1990 and Winter of 1990-91 were also relatively dry however and we are currently, in 1991-92, in the third successive year of reduced rainfall. Due to the groundwater storage within the chalk aquifer, groundwater baseflow continues to be released even during the Summer, but the effect is that the aquifer becomes progressively depleted.

One of the current areas of research as a result of the 1989-92 drought is the identification of the most critical length of drought for various aquifers and catchment types. These studies have not yet been completed (BHS Occasional Paper No. 3 - due to be released in Summer 1992) but it is understood that the critical period for a major chalk block such as the Berkshire Downs may be in the region of 2 to 5 years. In this context it is reported (Institute of Hydrology, pers. comm) that the current (to end January 1992) 42 month rainfall total for the Upper Thames Valley, which includes the Kennet, is the lowest since records began in 1893. In addition to the reduced rainfall, the temperatures in the Summers of 1989 and 1990 (but not 1991) were significantly above average, increasing the evapotranspiration losses from the catchment.

9.3 Data Analysis

The rainfall and percolation data used in these analyses are from the NRA-Thames database of areally averaged data over the Berkshire Downs chalk block. The meteorological years are calculated from October to September. Figure 9.1 shows the annual rainfall and Figure 9.2 the annual percolation over the period of record from 1920/21 to 1990/91. The following points can be made from these plots :

- The six lowest rainfall years over the record, in order of decreasing severity, are 1975-76, 1933-34, 1920-21, 1928-29, 1988-89 and 1943-44.

- The six lowest percolation years over the record, again in order of decreasing severity, are 1975-76, 1933-34, 1943-44, 1964-65, 1990-91 and 1928-29.

- The most severe single year event is, clearly, 1975-76. There was an almost total failure of Winter rainfall in this year and this is reflected in the groundwater hydrographs (section 4) which did not recover during the Spring. Flows during the following, very hot Summer were reduced to minimum levels. However, this was a single year event and the rainfall in the winter of 1976-77 was a near maximum over the data period. Therefore, although the chalk was quite severely stressed, the effect was not cumulative over more than one year.

- 1933-34 is similar to, but less severe than 1975-76, in that a failure of Winter rainfall resulted in reduced surface flows being recorded in the upper reaches of the river. The flow record shows a failure of the springs during the whole of 1934 (see Section 5). Again, as with 1975-76, the rainfall in the following Winter was relatively high and replenished the aquifer.

- The reduction of surface flows recorded in 1921-22 (Section 5) correlates well with reduced percolation over the period from 1920-22, indicating that this was a 2 year event.

- The drought period described by Colonel Maurice, but not dated, would appear to have been of 1943-44. This drought may be the most comparable with the current drought period as reduced rainfall totals were recorded in three successive years (1941-44) and reduced percolation totals in five (1941-46). Of these years, the most severe were 1943-44 and 1942-43; 1944-45 and 1945-46 were not significantly below average.

- It is already noted that the current 42 month drought period is the most severe in the 100 year record for the Upper Thames Region. The data on Figures 9.2 and 9.3 do not include 1991-92 which is likely to be another year of reduced rainfall. Rainfall and percolation are recorded as being below the mean from 1988 to 1991. 1989-90 was not a particularly dry year, but both 1988-89 and 1990-91 were among the ten driest years in the period of record.

As noted in Section 9.2 above, the most severe drought period for the chalk aquifer is considered to be between 2 and 5 years. Figures 9.3 and 9.4 have been prepared in this context and show the three year running means for both rainfall and effective rainfall over the period of record. Accepting the primacy of the 3 year period with regard to drought severity, these plots show the following :

- The rainfall over this current period (1988-91) is 125mm, or 17 per cent, below the mean rainfall for the 70 year record. This is comparable with the periods 1920-23 (150mm) 1932-35 (125mm) and 1942-45 (125mm).

- The percolation over the 1988-91 period is 100mm, or 34 per cent, below the mean for the record. This is comparable with 1942-45 (110mm) 1932-35 (90 mm) and 1920-23 (95mm).

- The current drought is among the worst four long period droughts of the last 70 years and is the worst since 1945.

A five year running mean has also been analysed. The minimum totals, in ascending order, are from 1972-76, 1962-66, 1987-91 and 1942-46. These dates do not appear to correspond as precisely with the known periods of low groundwater levels as the 3 year running means. It is considered that, for the Kennet catchment, the critical drought stress period is in the region of 1 to 3 years.

The impact of reduced rainfall on surface flows and a comparison of the impact of natural drought and groundwater abstraction is included in Section 14.

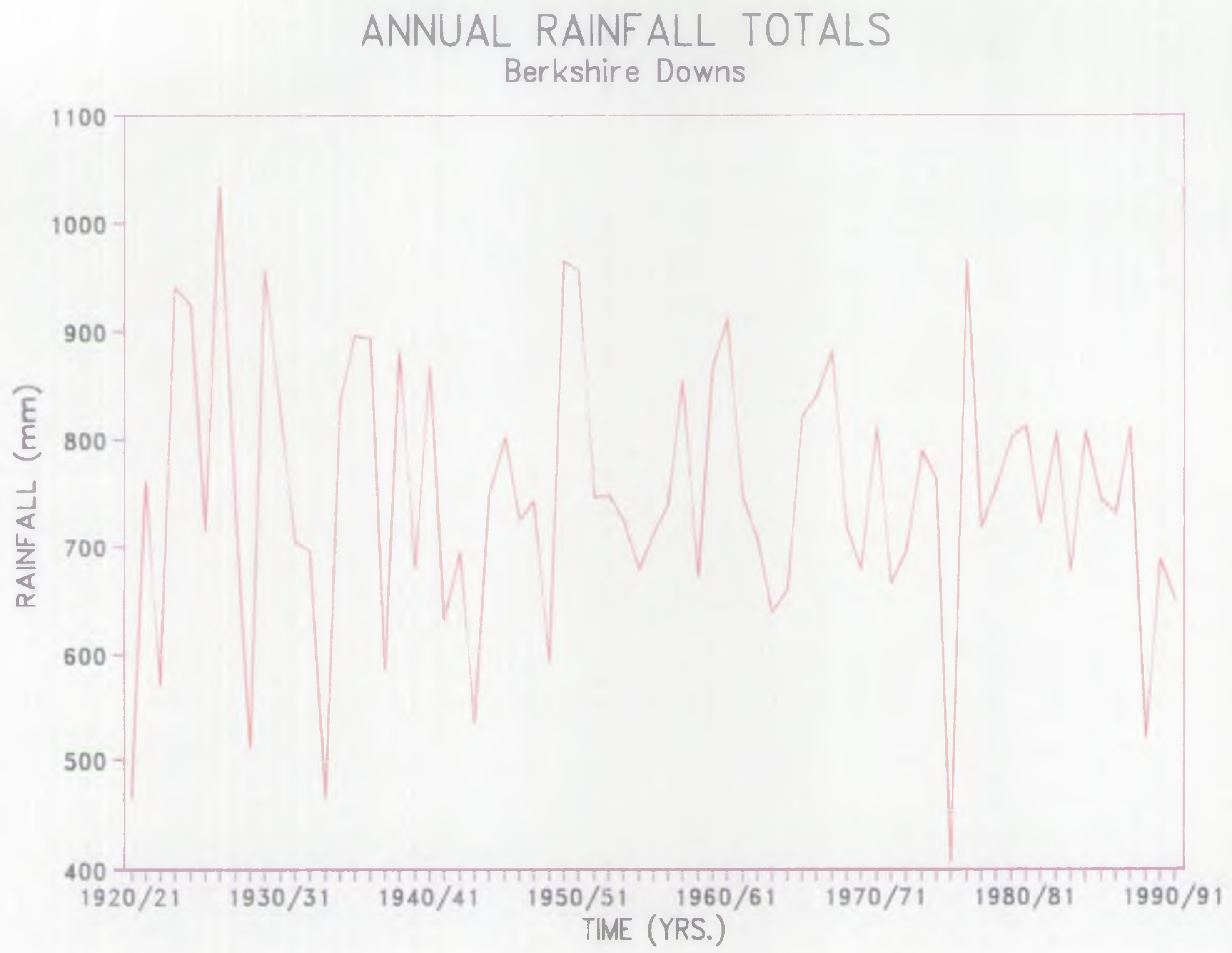
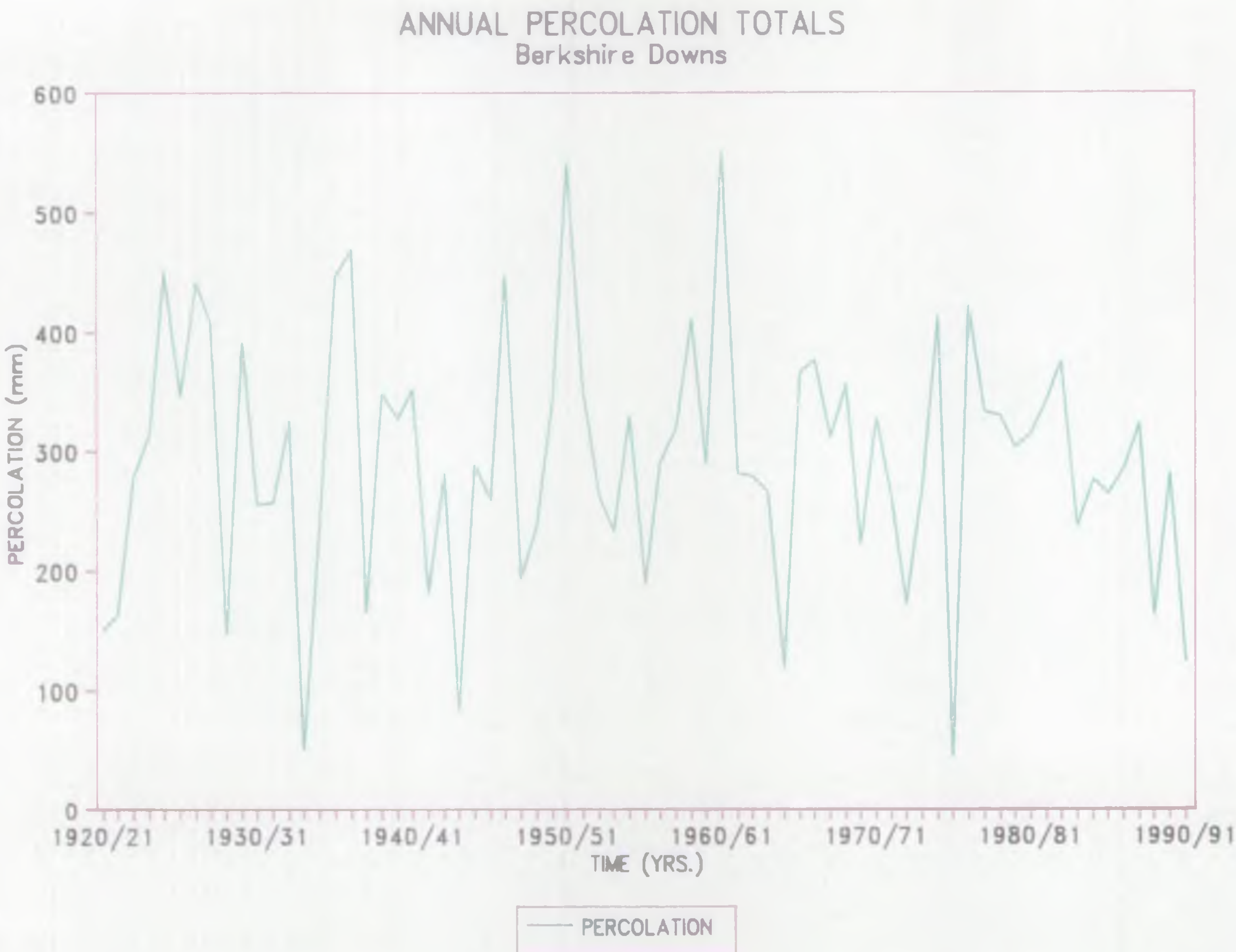

ANNUAL RAINFALL TOTALS
Berkshire Downs
RAINFALL (mm)
1100
1000
900
800
700
600
500
400
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)

FIGURE 9.1



ANNUAL PERCOLATION TOTALS
Berkshire Downs
PERCOLATION (mm)
600
500
400
300
200
100
0
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
PERCOLATION

FIGURE 9.2

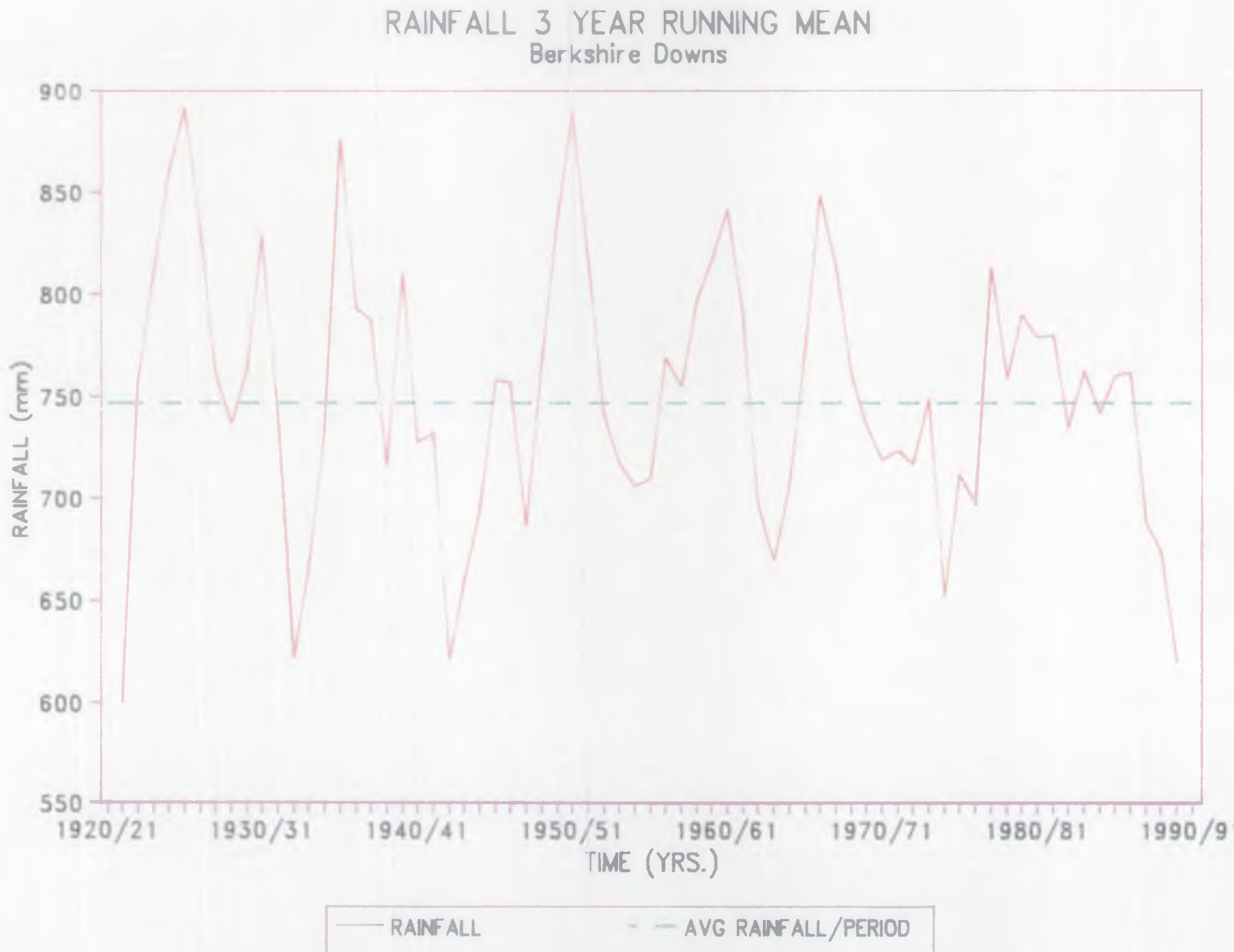

RAINFALL 3 YEAR RUNNING MEAN
Berkshire Downs
900
850
800
750
700
650
600
550
RAINFALL (mm)
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
RAINFALL
AVG RAINFALL/PERIOD

FIGURE 9.3

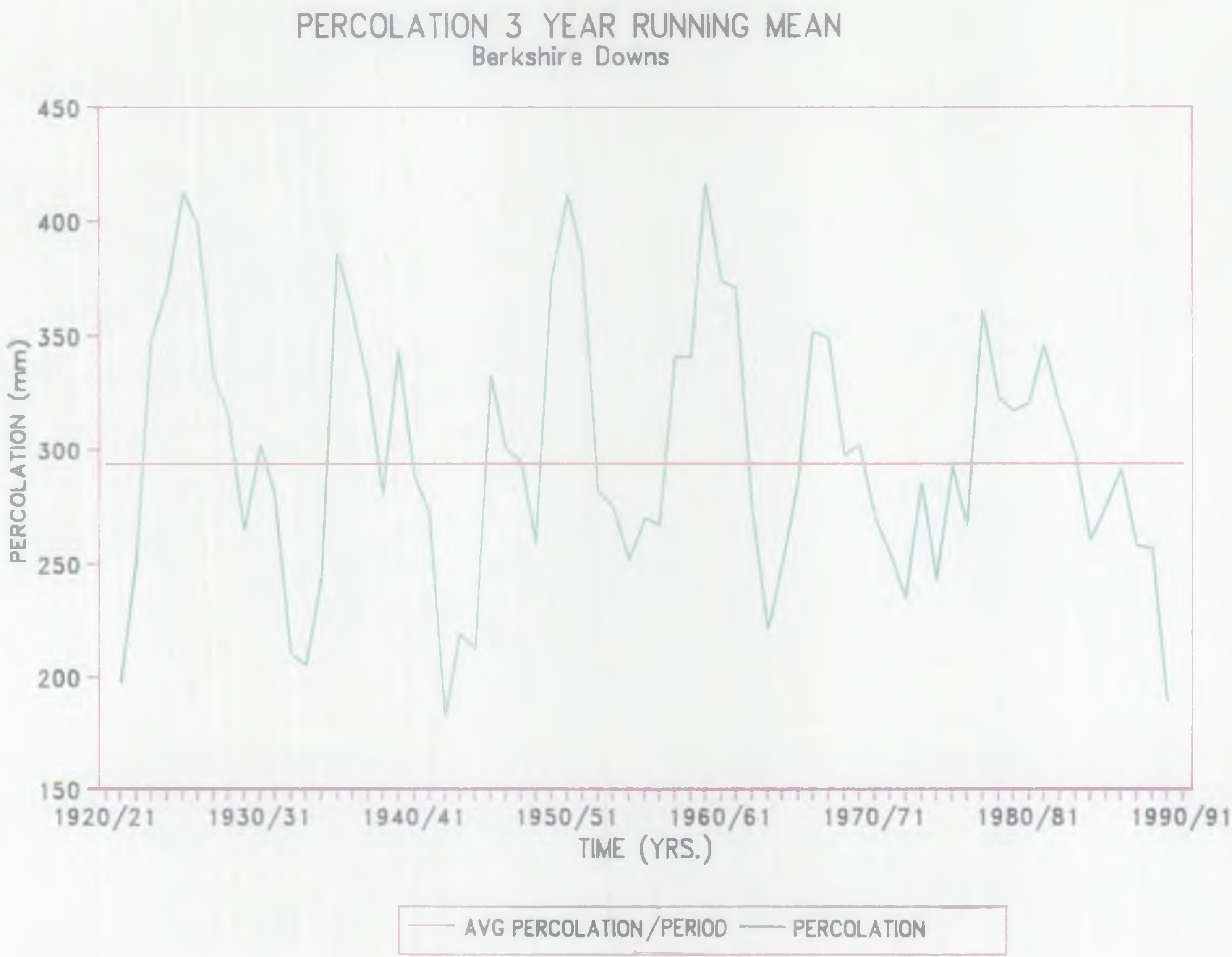

PERCOLATION 3 YEAR RUNNING MEAN
Berkshire Downs
450
400
350
300
250
200
150
PERCOLATION (mm)
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
AVG PERCOLATION/PERIOD
PERCOLATION

FIGURE 9.4

10. ABSTRACTION

10.1 General

The major use of groundwater abstracted from the catchment is for public water supply. In addition to the major public supplies, however, there are a large number of private licences within the catchment. The individual licensed abstraction rates are generally very small; agricultural licences comprise the only other significant category to public supply but amount to only 5 per cent of the total licensed abstraction. Only public water supplies have been considered for the purpose of this study therefore.

Chalk groundwater has been used for potable water supply to the area for a long time and the earliest wells known are of Roman origin, located in the East Kennett area. Up until the late nineteenth century water supply was essentially a local issue, most large houses would operate their own wells and smaller houses would be supplied either direct from the river or from the 'village pump'.

The first public water supplies in this area appear to have been developed in the late nineteenth century, first at Shepherds Shore (1877), followed by Marlborough (1885) and Ogbourne, also at or before the turn of the Century. Public water supplies were developed further during this Century and received a boost with the 1945 Water Act. Clatford borehole was installed, following a Public Enquiry, in 1948 to supply the villages in the Upper Kennet Valley above Marlborough. Swindon Borough Council developed the large source at Axford largely to supply the growing requirements of Swindon although approximately 25 per cent of the supply is used within the catchment. This borehole supplemented the existing supply to Swindon from the Ogbourne source.

Licensed maximum abstraction totals were set under the 1963 Water Act. A number of upward revisions have taken place since (see Table 10.1), the most notable being at Axford where the current licensed maximum daily abstraction is 20.5 Ml/d. This is linked to a flow restriction at Knighton Gauge such that once the surface flow reduces below 61.4 Ml/d the licensed daily maximum is reduced to 13.1 Ml/d. The Axford licence is due for review in 1994.

A Drought Order was issued in 1990 under which Thames Water were granted temporary licences to abstract at Avebury (3 Ml/d) and Ogbourne (4 Ml/d) and the flow restriction on the Axford source was reduced from 61.4 to 30 Ml/d.

The abstraction licences were operated for a total of 2 weeks and 5 weeks respectively in November and December 1990 and the licences are no longer valid.

A full list of the current public supply boreholes in and around the catchment is given in Table 10.1 and the locations are marked on Figure 10.1. Yatesbury and Shepherds Shore sources are within the surface water catchment but outside the groundwater catchment whereas Cherhill is outside the surface and groundwater catchment. The likely impact of these abstractions on the water resources of the Kennet catchment is considered further in Section 10.2.

10.2 Assessment of the Impact of Groundwater Abstraction

Methodology

The 'natural' surface flow regime of a catchment is that which would occur if there were no artificial influences upon it. The two significant artificial influences which impact upon the Kennet, as on most catchments, are abstraction for supply and effluent discharge. This sub-section considers the changes in the natural flow regime over the last 30 years caused by the actual abstraction and discharge rates over this period.

The mean flow and Q95 (or low Summer) flow have been calculated at the relevant gauging stations for each year of gauged record and are shown on Table 10.2. Mean abstractions for each public supply source have been collated for each year and the October of each year. Actual groundwater abstraction data are confidential, so the data have been totalised for (i) the Wessex Water group - those on the western margins of the catchment and (ii) the Thames Water group and are shown on Table 10.2.

The only two significant effluent discharges to the catchment are at Fyfield and Marlborough sewage treatment works (see Figure 10.1). There is no regular gauging of the effluent discharge from either works but data are available for the mean annual discharges between 1983 and 1987. The mean daily actual discharge over this period, of 0.5 Ml/d (Fyfield) and 3.5 Ml/d (Marlborough), have been used during the subsequent analyses.

The method of analysis has been to express both gross abstraction (i.e. the abstraction total) and nett abstraction (i.e. abstraction total minus discharge total) as a percentage of the 'natural' surface flow. The flows have been 'naturalised' by adding the abstraction total to and subtracting the discharge from the actual flow record.

This method of analysis is valid as long as changes in groundwater storage are not significant in relation to the flow volumes. If changes in storage are significant this method produces the sum of the reduction in (i) natural flow and (ii) groundwater storage. During low flow periods the change in storage may contribute a significant proportion of the total nett abstraction, resulting in the actual effect on flows being less than that calculated.

The contribution of storage under low flow conditions appears to be controlled by (i) the available surface resources and (ii) the hydraulics of the particular case. Where actual flows are low, storage may contribute, say, half of the total abstraction, but individual cases may vary considerably around this estimate. The percentage impact calculated below is likely to be a conservative figure.

It is important to remember that all the assessments made below are estimates only but are useful as indicators of the scale of the influence of abstraction on natural flows.

Catchment to Marlborough

One of the uncertain issues at the start of the Study was the impact, if any, of abstraction from the three public supply sources around the western surface catchment boundary, operated by Wessex Water, on the water resources of the Upper Kennet catchment. All three sources are outside the groundwater catchment area of the Kennet, as defined from the low groundwater contours from 1989 and shown on Figure 10.1, and lie within the groundwater catchment of the Bristol Avon to the west.

This does not prove that the sources are not impacting upon the natural catchment resources of the Kennet however as (i) the areas of influence of the boreholes (defining the aquifer volume contributing to groundwater abstraction) may extend to the east of the groundwater catchment divide and/or (ii) the effect of abstraction from these sources may have been to shift the groundwater catchment boundary to the east. Their location does indicate however that at least half of the 'Wessex' groundwater supply is sourced from the Bristol Avon catchment.

The actual yield of the Wessex sources varies from 0.5 to 2.0 Ml/d. The mean percolation over the catchment is in the order of 300mm per year. The percolation area required to supply the borehole sources is therefore in the order of 0.5 to 2.5 km^2.

The Wessex sources are between 2 and 3.5 km west of the estimated line of the groundwater divide and it is considered probable therefore that most if not all of the yield is at the expense of the Avon catchment. It is estimated, on this basis, that 25 per cent is a likely maximum for the percentage of source yield from the Kennet catchment.

As this is only an estimate, sensitivity analyses have been carried out to assess the effect of varying the influence of the Wessex boreholes on the Kennet catchment. Three assessments have been made, expressing abstraction as a percentage of the natural flow to the Marlborough gauge, and assuming that (i) 100 per cent, (ii) 25 per cent and (iii) 0 per cent of the Wessex abstractions are at the expense of the Kennet catchment.

As the Marlborough source is close to the gauging site it is also assumed, in each assessment, that 50 per cent of the abstraction at Marlborough PS is at the expense of flows to Marlborough gauge.

Gross actual abstraction from the catchment to Marlborough is expressed as a percentage of mean flow and Q95 flow for each year of the gauged record since 1973, using each of the three 'Wessex percentages' in the sensitivity analysis. The results are shown on Table 10.2 and option (ii) - Wessex abstraction at 25 per cent - is illustrated in Figure 10.2.

Nett abstraction, assuming a Wessex percentage of 25 per cent, is expressed by incorporating the mean effluent return from Fyfield STW of 0.5 Ml/d. The results are shown on Table 10.2 and illustrated on Figure 10.3.

The main findings of these data are considered below.

- Total abstraction is a very low percentage of the natural mean flow to Marlborough. Even assuming that all the western boreholes are abstracting directly from the Kennet catchment the abstraction is approximately 4 per cent of the mean flow (assessment (i) on Table 10.2). Under the best conservative estimate of 25 per cent, abstraction reduces to 2 per cent of mean flow (assessment (ii) on Table 10.2 and illustrated in Figure 10.2).

- The nett abstraction for the catchment above Marlborough results, on average, in a reduction in the mean natural flow at Marlborough of only one per cent. Nett abstraction reduces the natural Q95 (or low Summer) flow by a typical maximum of 5 per cent. The exception to this is in 1976; however the natural flow calculated for 1976 was also virtually zero and the majority of abstraction, from Clatford at least, was probably at the expense of groundwater storage.

It would appear therefore that groundwater abstraction within the upper catchment results in only a minor reduction in the natural surface flow. As a comparison, reduced effective rainfall over the current 3 year drought period is assessed (from Section 9) as having reduced percolation (and, by extension, natural mean flow) by approximately 35 per cent (i.e. 35 times as great as the nett impact of abstraction).

The influence of changing sewage disposal in the upper catchment from local and individual soakaways to a sewage system centralised at Fyfield has been considered. The foregoing analyses indicate that the sewage returns to this catchment are not a significant influence on its character. It is considered that soakaways were a more effective method of returning effluent to the groundwater resource. However, the location of Fyfield is also beneficial from the resources viewpoint in providing some flow to the upper reaches during drought periods.

Total Catchment to Knighton

The total gross abstraction from the catchment to Knighton, expressed as a proportion of the naturalised mean annual and Q95 flow at Knighton gauge, is also given in Table 10.2 and is illustrated in Figure 10.4. This assessment incorporates the assumption that 25 per cent of the Wessex abstractions are at the expense of the Kennet catchment. All other abstractions are included at 100 per cent.

The nett abstraction to Knighton, incorporating the discharges from Fyfield and Marlborough STW, is illustrated in Figure 10.5.

The main findings of these analyses are considered below:

- The total actual groundwater abstraction increased steadily between 1964 and 1977. In 1978 and 1979 abstraction increased rapidly by over 10 Ml/d. Subsequent to this, abstractions have decreased steadily. Actual abstraction last year (1991) was approximately double that recorded in 1964, at 20 Ml/d.

- Total actual abstraction increased over the period of record, as a percentage of naturalised mean flow, from 5 per cent to 10 per cent. Two per cent of mean flow was returned to the catchment as effluent.

Consequently actual mean flows were reduced below natural by approximately 3 per cent in the 1960's and 8 per cent by 1990.

- The impact of abstraction on late Summer low flows (Q95 flows) appears to have increased at a slightly greater rate than the impact on mean flows. The maximum nett impact has increased from below 10 per cent to approximately 25 per cent over this period. If it is assumed that half of the yield during low flows is from groundwater storage the current low flows are reduced below the natural flow by between 10 and 15 per cent.

These findings above correlate reasonably well with the double mass flow analyses discussed in Section 5 which identified a mean reduction in surface flow in the order of 10 to 15 Ml/d, dating from the early to mid 1970's.

The nett impact of abstraction and discharge on the Upper Kennet catchment to Knighton has been assessed as approximately 8 per cent. The effective rainfall experienced in the catchment over the 3 year drought period is considered to be reduced by 35 per cent relative to the long term mean (see Section 9). The overall impact is therefore to reduce mean flow rates by 40 per cent or so. Approximately four fifths of this impact is therefore attributable to the natural long term drought and one fifth is due to the nett impact of groundwater abstraction.

The impact on low flows is more difficult to assess. Low flows are affected more acutely than mean flows by drought and, probably, by abstraction. However, the proportional impacts may well remain similar.

The River Og Catchment

A separate analysis has been made of the River Og catchment to its confluence with the River Kennet at Marlborough. There is no effluent return to the catchment so the actual abstraction represents the total nett influence on surface flows. The main findings of these analyses are considered below. The data are shown on Tables 10.2 and 10.3 and plotted on Figure 10.6.

- Abstraction has remained fairly consistent at about 6 Ml/d and has actually declined slightly over the 30 year period.

- Abstraction has been estimated as reducing the natural mean flow in the River Og by approximately 20 per cent.

- The impact of abstraction on low flows appear to be more significant. Assuming that 50 per cent of the yield is from storage, abstraction reduces low Summer flows by approximately 30 per cent.

Abstraction from Ogbourne pumping station on the Og therefore appears to be responsible for approximately two fifths of the total reduction in flows during the current drought.

Licensed Groundwater Abstraction

Licensed abstraction is also considered as this illustrates the maximum potential effect on surface flow under existing licences.

Figures 10.7 to 10.9 illustrate the total nett licensed annual abstraction for the Kennet catchment to Marlborough and Knighton and the River Og respectively, incorporating licensed annual abstractions and actual effluent returns. The data are considered in terms of Ml/d and as a percentage of natural annual mean flow and are listed in Table 10.4. The main findings are summarised below :

- Abstraction up to the licensed limit does not appear to have a significant effect on the catchment upstream of Marlborough.

- Licensed abstraction in the total catchment to Knighton includes, for 1990, the temporary licences granted under drought order at Avebury and Ogbourne. The maximum nett abstraction under licence would have resulted, in recent years, in a reduction of 15 per cent in natural mean flow. This compares with the actual reduction of 8 per cent.

- Licensed abstraction in the River Og catchment in 1991 would have reduced natural mean flow in the catchment by over 30 per cent.

TABLE 10.1 : Details of Groundwater Supply Sources

PUMPING STATION	GRID REFERENCE	YEAR COMMENCED	LICENCE (Ml/d)		YEAR GRANTED	LICENCE REVIEW (Ml/d)		YEAR REVIEWED
			Daily	Annual		Daily	Annual	
Clatford	SU158 689	1947	1.1	0.9	1966	1.5	1.2	1975
Marlborough	SU192 682	1885	2.6	1.9	1966	3.1	2.5	1975
Ramsbury	SU275 720	1925-1965(?)	1.9	1.0	1966	1.9	1.2	1973
Ogbourne	SU191 762	pre 1902	13.5	7.5	1966	-	-	-
Axford	SU246 709	1948-49	10.5	9.3	1965	20.5*	13.7	1984
Yatesbury	SU060 702	1908	0.9	0.9	1967	-	-	-
Shepherds Shore	SU048 668	1877	2.8	2.5	1967	4.0	2.8	1984
Cherhill	SU048 697	1936	1.4	1.4	1970(?)	-	-	-
Avebury**	SU089 701	1990	3.0	3.0	1990	-	-	-
Ogbourne**	SU200 754	1990	4.0	4.0	1990	-	-	-

* Reduced to 13.1 Ml/d if flow at Knighton GS reduces below 61.4 Ml/d

** Temporary Licence granted under 1990 Drought Order

KENNET AND COLN RIVER LEVEL STUDY

KENNET

ACTUAL ABSTACTION DATA (Ml/d)

		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Wessex Abstraction															
	Ann.						0.4	1.4	1.6	1.8	1.8	1.9	0.8	1.4	1.1
	Oct.						1.4	1.2	1.7	1.4	2.3	1.7	0.2	1.4	0.9
Thames Abstraction															
	Ann.	9.7	9.7	9.7	11.3	11.1	11.3	11.0	12.0	13.8	14.9	15.8	15.3	14.7	13.4
	Oct.	9.7	9.7	9.7	11.3	11.2	11.3	11.0	12.0	13.8	14.9	15.7	15.2	14.4	13.4

		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Wessex Abstraction															
	Ann.	3.1	3.2	2.8	2.9	3.3	3.0	3.2	3.2	2.9	2.8	2.0	2.7	2.3	2.8
	Oct.	2.8	2.8	2.8	2.8	2.9	2.8	2.4	2.5	3.0	2.5	2.0	2.3	1.9	1.9
Thames Abstraction															
	Ann.	15.5	23.4	23.4	21.5	19.6	22.2	21.5	19.3	19.2	19.6	19.4	18.7	18.2	18.3
	Oct.	15.8	23.0	23.3	21.3	19.3	22.4	21.3	19.2	19.0	19.8	19.3	18.4	18.1	18.2

NOTE : Actual Abstraction data has been grouped together, as individual values are confidential.
Wessex Abstraction = Cherhill, Shepherd Shore & Yatesbury.
Thames Abstraction = Ogbourne, Marlborough, Ramsbury, Clatford & Axford.

FLOW DATA (Ml/d)

Gauging Stations		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Marlborough	Mean										30.24	63.81	62.08	5.18	113.18
	Q95										11.23	19.87	10.37	0.00	27.65
Knighton	Mean	165.89	83.61	355.97	317.09	267.84	267.84	190.94	268.98	220.32	117.50	247.10	255.74	41.47	306.72
	Q95	72.58	52.78	153.79	117.50	140.83	67.26	69.98	101.95	75.17	65.66	89.86	55.30	12.10	113.18
Ogbourne	Mean														
	Q95														

Gauging Stations		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Marlborough	Mean	62.94	65.54	74.30	62.08	96.50	61.22	68.56	82.08	68.13	76.03	76.03	42.34	60.48	
	Q95	12.10	17.28	18.14	30.24	19.01	18.14	13.82	23.33	21.60	20.74	15.55	8.64	4.32	
Knighton	Mean	233.28	231.55	218.88	243.65	268.11	237.60	196.99	231.55	240.19	225.50	216.00	130.47	153.79	
	Q95	58.18	71.71	81.22	119.23	75.17	69.98	62.21	93.31	83.60	86.40	74.30	38.88	32.83	
Ogbourne	Mean				28.51	33.70	31.10	24.19	28.51	30.24	27.65	27.65	12.96	24.19	
	Q95				10.37	3.45	3.45	0.86	5.18	4.32	3.45	2.59	0.86		

TABLE 10.2

KENNET AND COLN RIVER LEVEL STUDY

KENNET

ACTUAL ABSTRACTION EXPRESSED AS A % OF MEAN AND Q95 NATURALISED FLOW FOR EACH YEAR

Station	Assessment		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Marlborough	Gross (i)	a. Mean											6.89	2.74	1.57	28.86	1.40	4.30	4.22	4.40	4.08	3.73	4.27	5.09	4.45	3.63	4.19	4.25	7.11	4.31	
Gauging Station		a. Q95											20.10	9.99	6.62	137.04	4.90	22.92	16.43	15.15	9.99	15.32	16.56	17.37	12.12	13.70	12.91	17.96	24.91	37.68	
	(ii)	b. Mean											2.76	1.10	0.65	15.36	0.68	1.64	1.56	1.73	1.54	1.33	1.64	1.80	1.69	1.27	1.56	1.53	2.73	1.60	
		b. Q95											8.33	4.32	5.26	100.00	2.60	10.42	6.67	6.37	3.66	5.97	7.35	6.96	5.29	4.95	5.27	6.96	16.70	18.64	
	(iii)	c. Mean											1.33	0.54	0.61	9.65	0.44	0.72	0.64	0.61	0.67	0.51	0.74	0.66	0.73	0.45	0.66	0.59	1.16	0.66	
		c. Q95											3.59	2.27	4.82	100.00	1.81	5.31	2.69	3.02	1.65	2.37	3.82	2.92	2.77	1.63	2.41	2.59	4.68	9.46	
	Nett	d. Mean											1.14	0.50	0.24	6.32	0.24	1.04	0.96	1.07	0.94	0.83	1.04	1.06	1.06	0.70	0.91	0.86	1.57	0.76	
		d. Q95											4.06	1.65	0.48	100.00	0.61	6.56	3.89	3.72	2.26	3.43	4.73	3.49	3.22	2.70	2.93	3.66	5.21	7.99	
Knighton	Gross	a. Mean		5.65	10.84	2.66	3.46	4.04	4.14	6.01	4.50	6.10	11.91	6.27	5.80	28.66	4.32	6.63	9.61	10.17	8.49	7.23	6.95	10.36	6.12	7.76	6.47	6.67	13.26	11.14	
Gauging Station		a. Q95		12.39	18.61	6.08	9.05	7.57	12.27	14.62	11.26	18.39	20.06	15.61	22.92	64.55	11.09	23.81	25.93	23.67	16.03	21.96	25.93	27.34	16.17	19.84	19.71	22.17	35.23	39.16	
	Nett	b. Mean		3.32	6.37	1.56	2.25	2.56	2.69	4.00	3.05	4.36	6.61	4.73	4.30	21.04	3.06	5.00	6.02	6.46	6.96	5.61	7.39	6.50	6.50	6.22	6.62	6.95	10.54	6.77	
		b. Q95		7.26	9.76	3.57	5.65	4.66	6.06	9.45	7.63	11.69	14.68	11.89	16.90	47.05	7.64	17.97	21.55	19.72	13.12	17.57	21.44	22.34	14.50	15.62	15.61	17.74	27.81	30.75	
Ogbourne		a. Mean																			19.26	14.03	18.49	19.34	16.66	16.79	20.20	16.34	26.20	14.79	
Gauging Station		a. Q95																			39.60	61.45	62.30	67.09	52.39	58.54	66.99	67.56	64.19		

NOTES:

GROSS : Abstraction as a proportion of naturalised flow.
MARLBOROUGH (i) : 'Wessex' abstraction * 1.0
(ii) : 'Wessex' abstraction * 0.25
(iii) : 'Wessex' abstraction not included.
NETT : Abstraction minus discharge as a proportion of naturalised flow.
KNIGHTON : Gross and Nett assessed from Wessex abstraction * 0.25

TABLE 10.3

KENNET AND COLN RIVER LEVEL STUDY

KENNET

LICENSED ANNUAL ABSTACTION DATA (Ml/d)

Pumping Station	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Cherhill							1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Shepherd Shore				2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Ogbourne			7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Marlborough			1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.5	2.5	2.5
Ramsbury			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.2	1.2	1.2	1.2
Yatesbury				0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Clatford			0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.2	1.2	1.2
Axford			9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Avebury														

Pumping Station	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cherhill	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Shepherd Shore	2.5	2.5	2.5	2.5	2.5	2.5	2.8	2.8	2.8	2.8	2.8	2.8	2.5	2.8
Ogbourne	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	11.5	7.5
Marlborough	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Ramsbury	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Yatesbury	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Clatford	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Axford	9.3	9.3	9.3	9.3	9.3	9.3	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Avebury													3.0	

FLOW DATA (Ml/d)

Pumping Stations		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Marlborough	Mean										30.24	83.81	82.08	5.16	113.15
Knighton	Mean	185.89	83.91	355.97	317.09	267.84	267.84	190.94	266.88	220.32	117.50	247.10	255.74	41.47	308.72
Ogbourne	Mean														

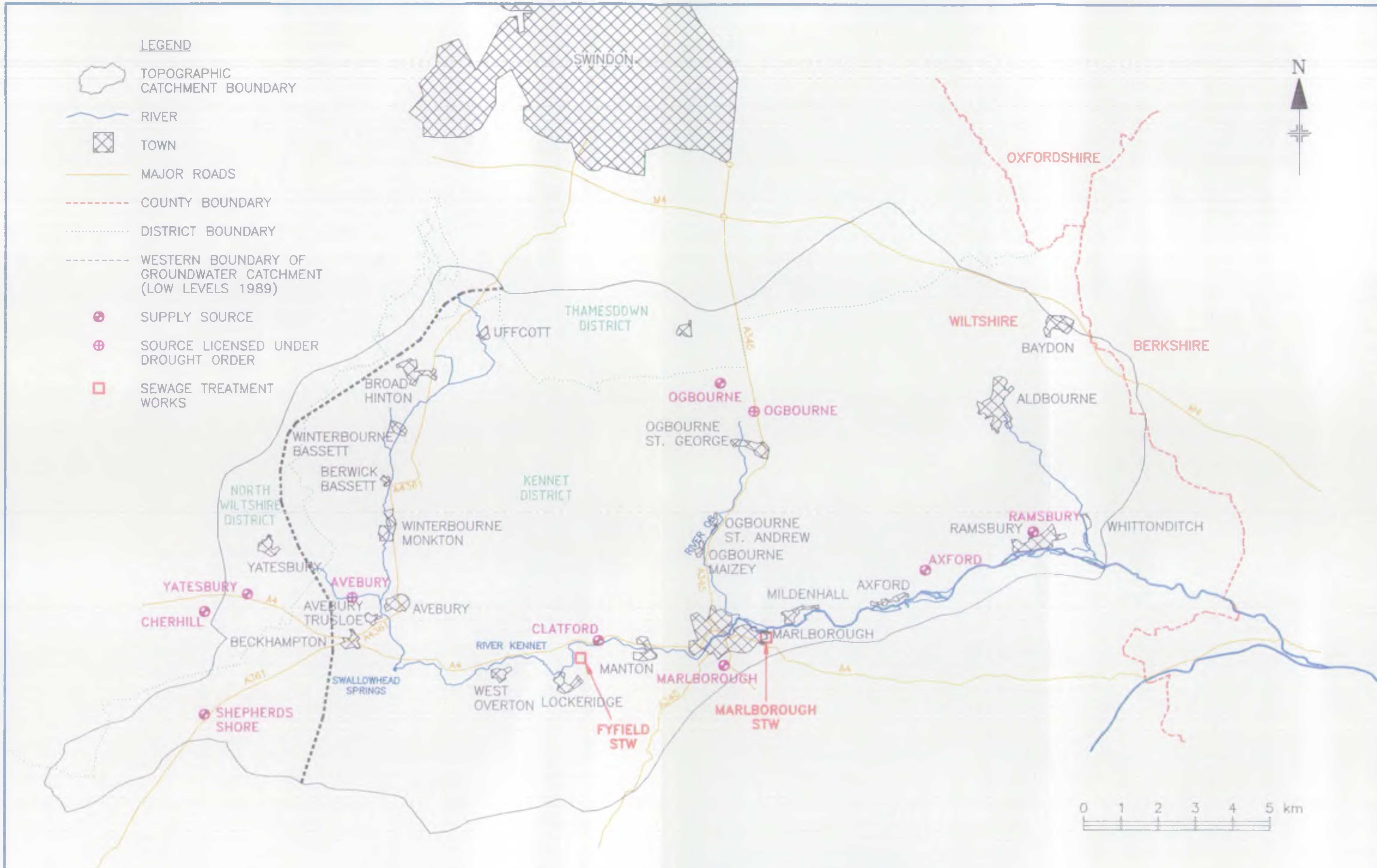
Pumping Stations		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Marlborough	Mean	82.94	85.54	74.30	82.08	98.50	61.22	68.56	82.08	86.13	76.03	76.03	42.34	60.48	
Knighton	Mean	233.28	231.55	218.86	243.65	266.11	237.60	198.99	231.66	240.19	225.50	218.00	130.47	153.79	
Ogbourne	Mean				28.61	33.70	31.10	24.19	28.51	30.24	27.65	27.65	12.96	24.19	

LICENSED ABSTRACTION EXPRESSED AS A PERCENTAGE OF MEAN NATURALISED FLOW FOR EACH YEAR

Gauging Station		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Marlborough	Gross (i)										15.00	5.93	6.21	53.55	4.57
	Gross (ii)										5.26	1.94	2.16	27.76	1.57
	Gross (iii)										1.49	0.54	0.73	11.36	0.53
	Nett										3.66	1.35	1.56	20.05	1.14
Knighton	Gross			5.53	6.41	7.52	7.52	10.44	7.66	9.16	16.24	8.30	8.34	37.93	7.03
	Nett			4.46	5.22	6.12	5.12	9.53	8.25	7.48	13.26	6.79	6.88	31.31	5.80
Ogbourne															

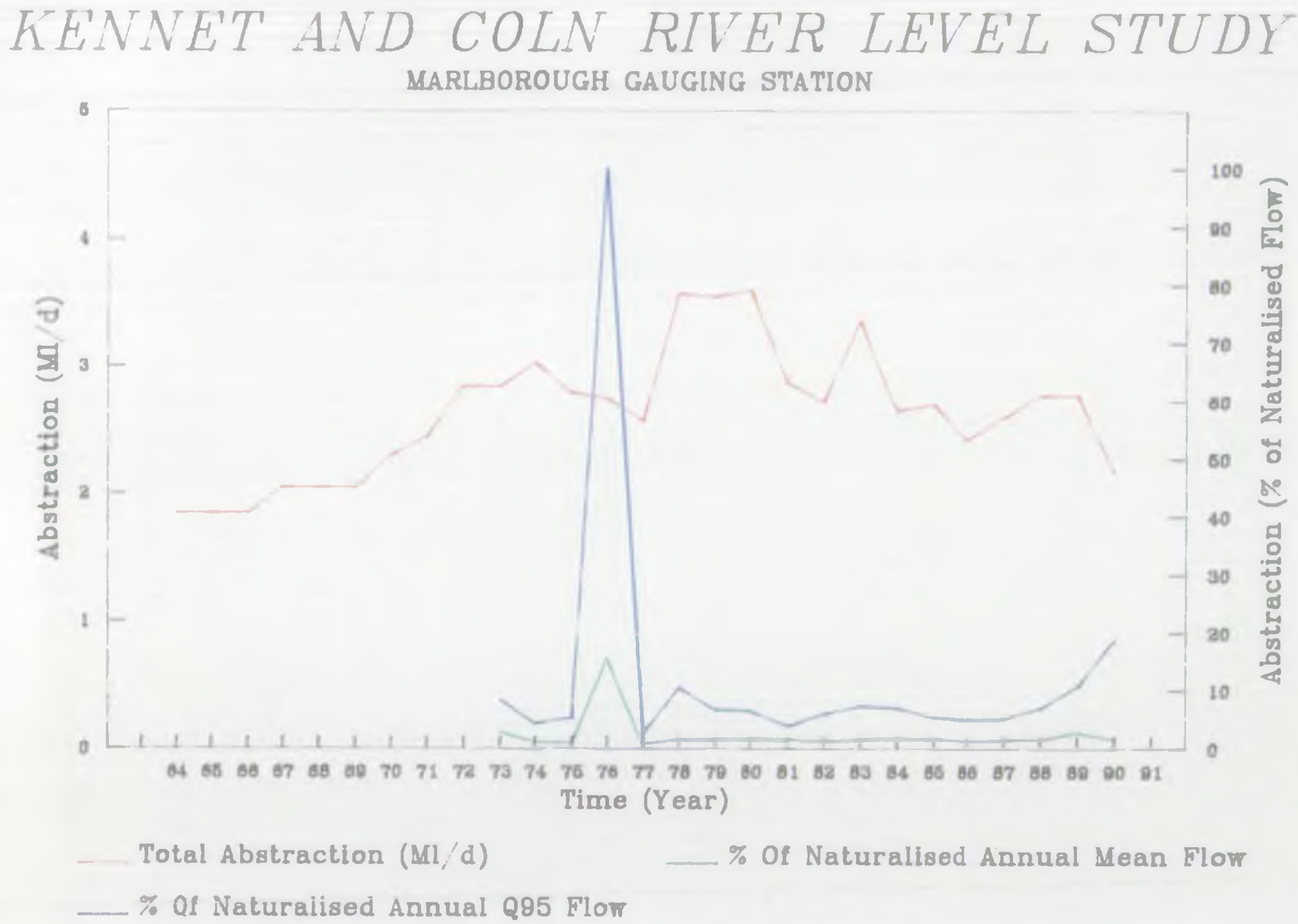
Gauging Station		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Marlborough	Gross (i)	6.15	5.97	6.62	6.21	5.22	6.27	7.73	6.63	6.11	7.02	7.02	11.99	6.69	
	Gross (ii)	2.14	2.07	2.36	2.10	1.80	2.16	2.66	2.25	2.09	2.42	2.42	4.29	3.03	
	Gross (iii)	0.72	0.70	0.81	0.73	0.61	0.74	0.87	0.73	0.68	0.79	0.79	1.41	0.99	
	Nett	1.54	1.50	1.72	1.56	1.30	1.68	1.97	1.65	1.64	1.78	1.78	3.15	2.22	
Knighton	Gross	9.08	8.14	9.71	6.72	8.03	8.93	12.42	10.74	10.39	11.00	11.44	17.79	17.32	
	Nett	7.49	7.55	8.02	7.20	6.63	7.37	10.61	9.17	8.67	9.39	9.77	15.19	15.11	
Ogbourne					20.63	18.20	19.43	23.67	20.83	19.87	21.34	21.34	36.66	32.22	

TABLE 10.4



UPPER RIVER KENNET CATCHMENT
PUBLIC SUPPLY SOURCES : LOCATION PLAN

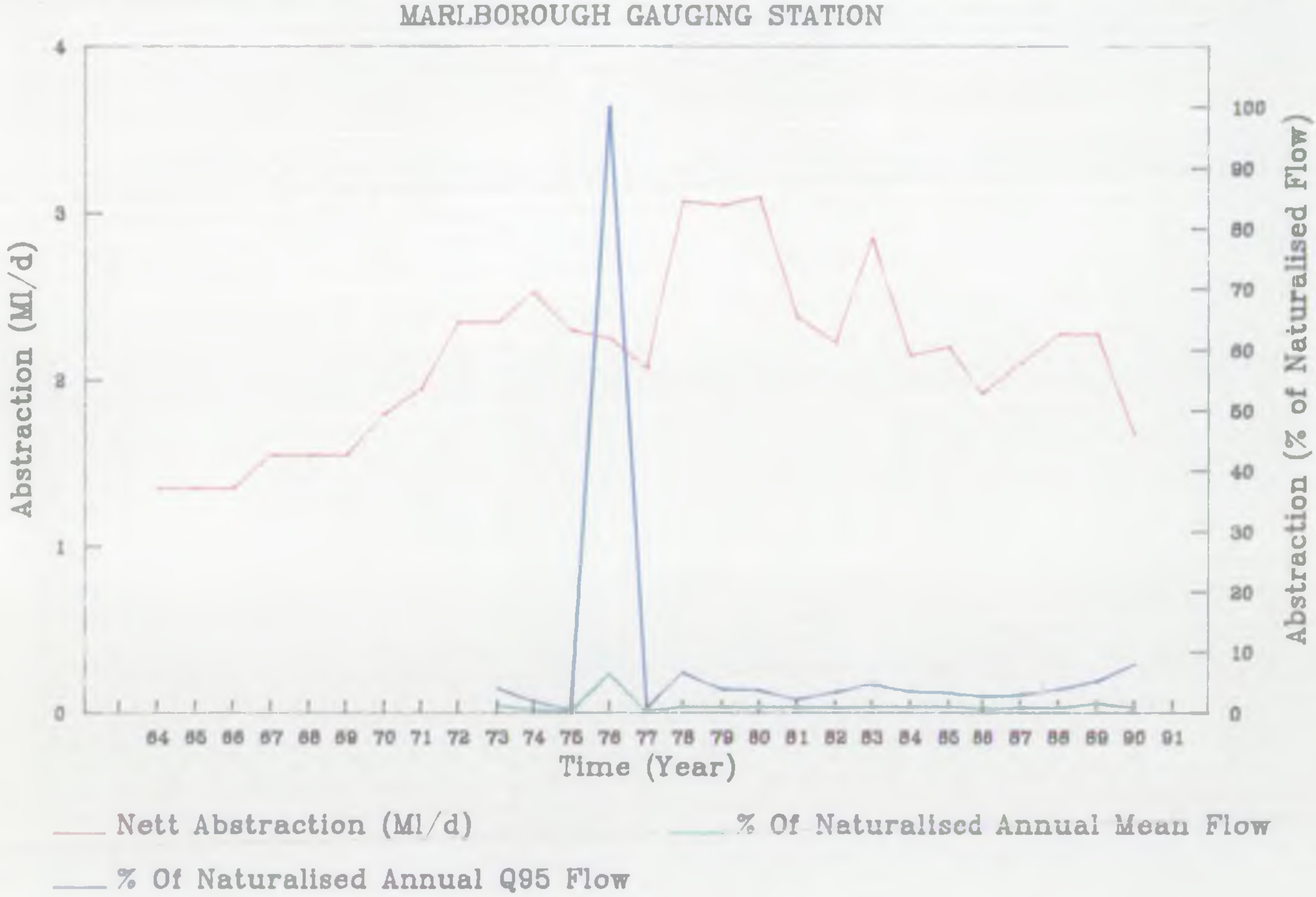
FIGURE 10.1



TOTAL ACTUAL ABSTRACTION TO MARLBOROUGH EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.2

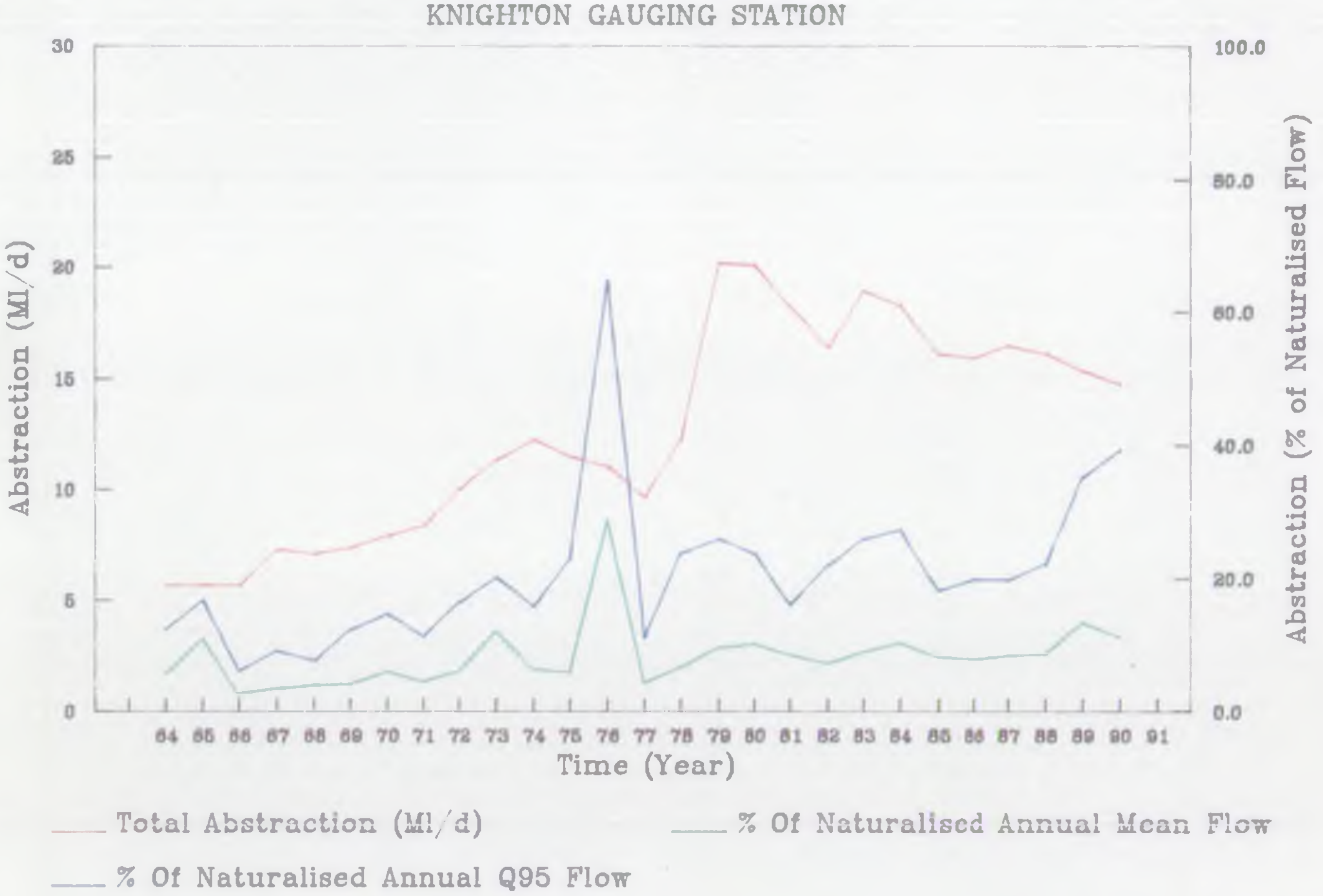
KENNET AND COLN RIVER LEVEL STUDY



TOTAL NETT ABSTRACTION TO MARLBOROUGH EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.3

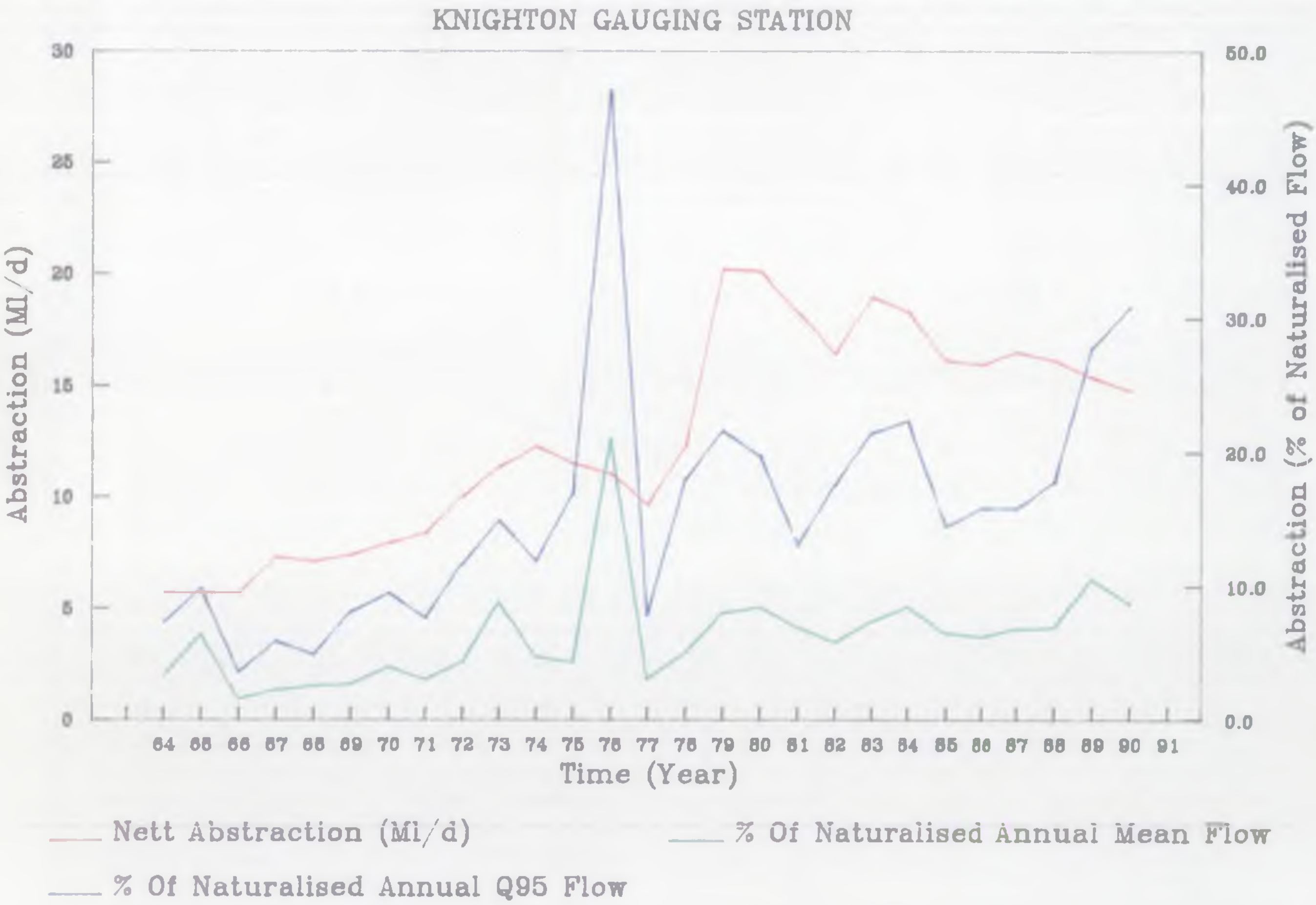
KENNET AND COLN RIVER LEVEL STUDY



TOTAL ACTUAL ABSTRACTION TO KNIGHTON EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.4

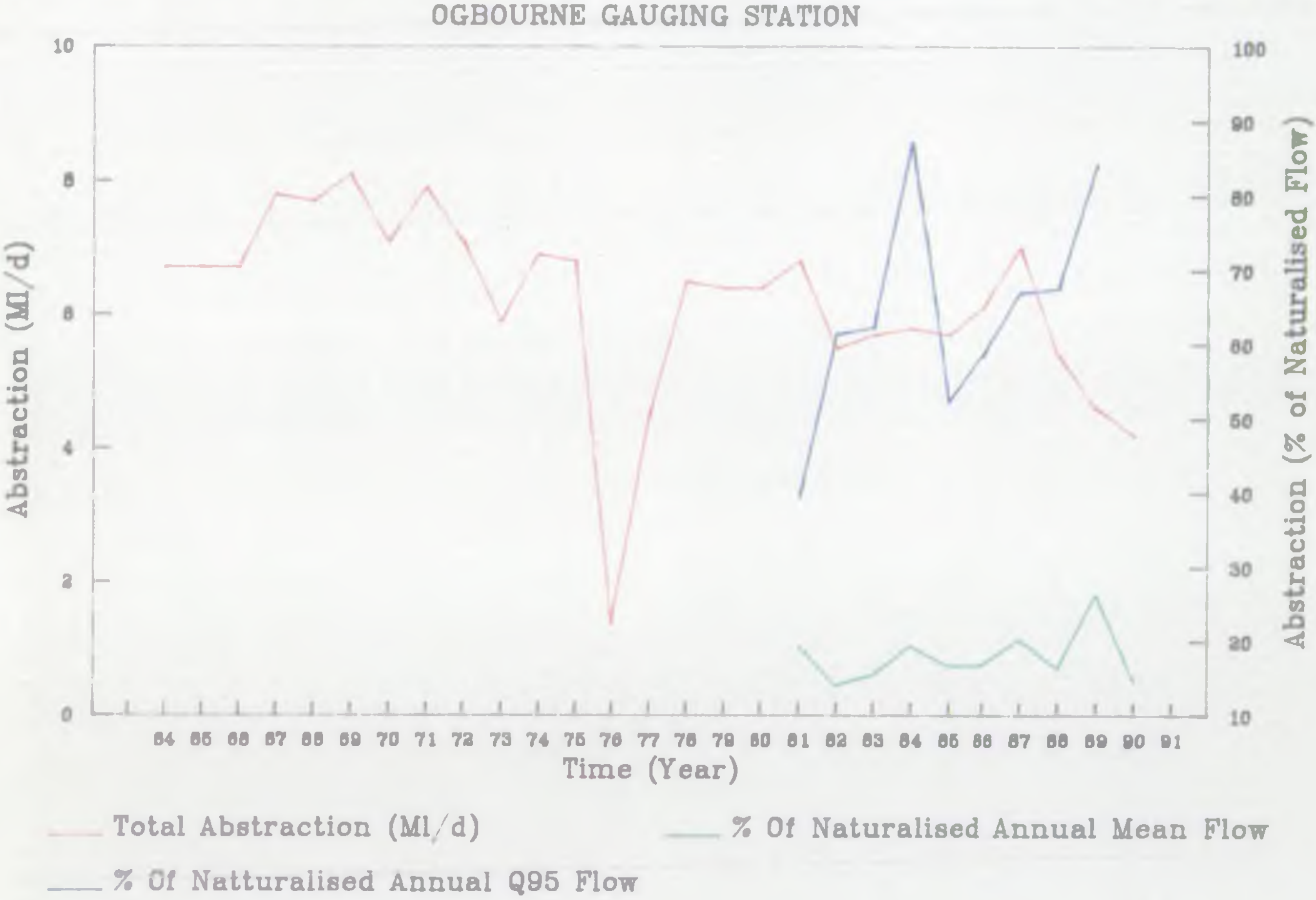
KENNET AND COLN RIVER LEVEL STUDY



TOTAL NETT ABSTRACTION TO KNIGHTON EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.5

KENNET AND COLN RIVER LEVEL STUDY

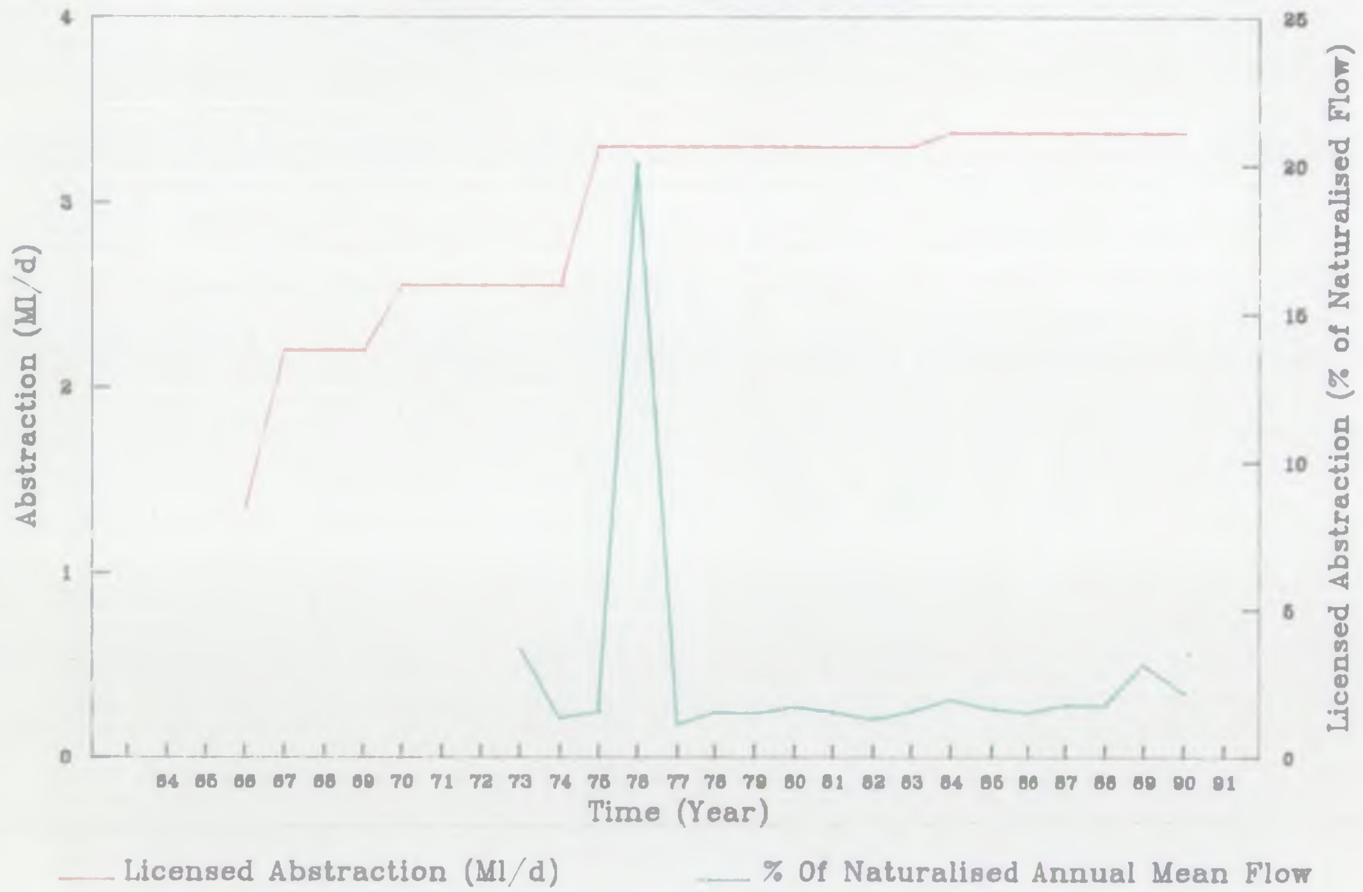


TOTAL ACTUAL ABSTRACTION FOR THE OGBOURNE SUB CATCHMENT EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.6

KENNET AND COLN RIVER LEVEL STUDY

MARLBOROUGH PUMPING STATION

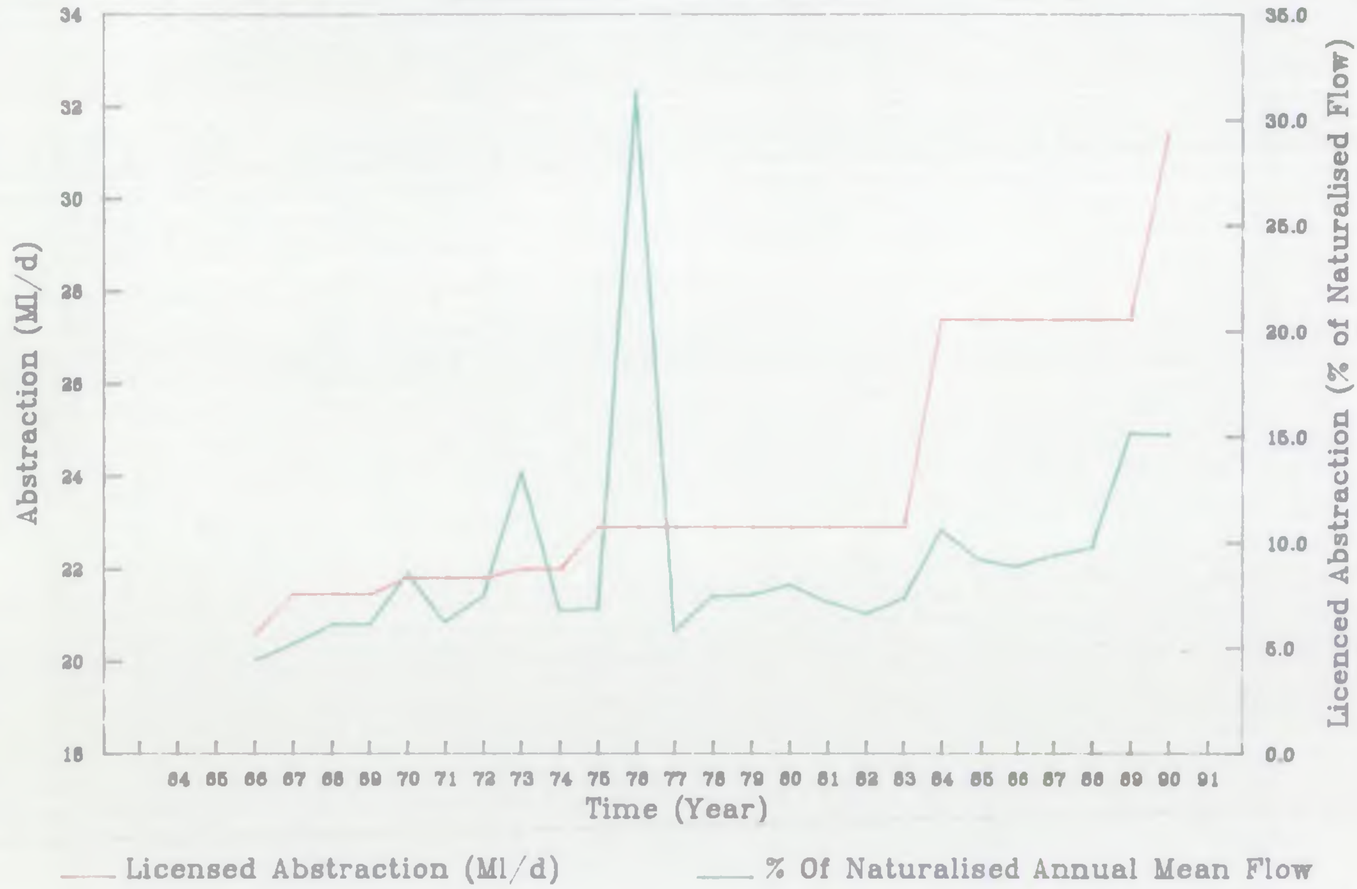


NETT LICENSED ABSTRACTIONS TO MARLBOROUGH EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.7

KENNET AND COLN RIVER LEVEL STUDY

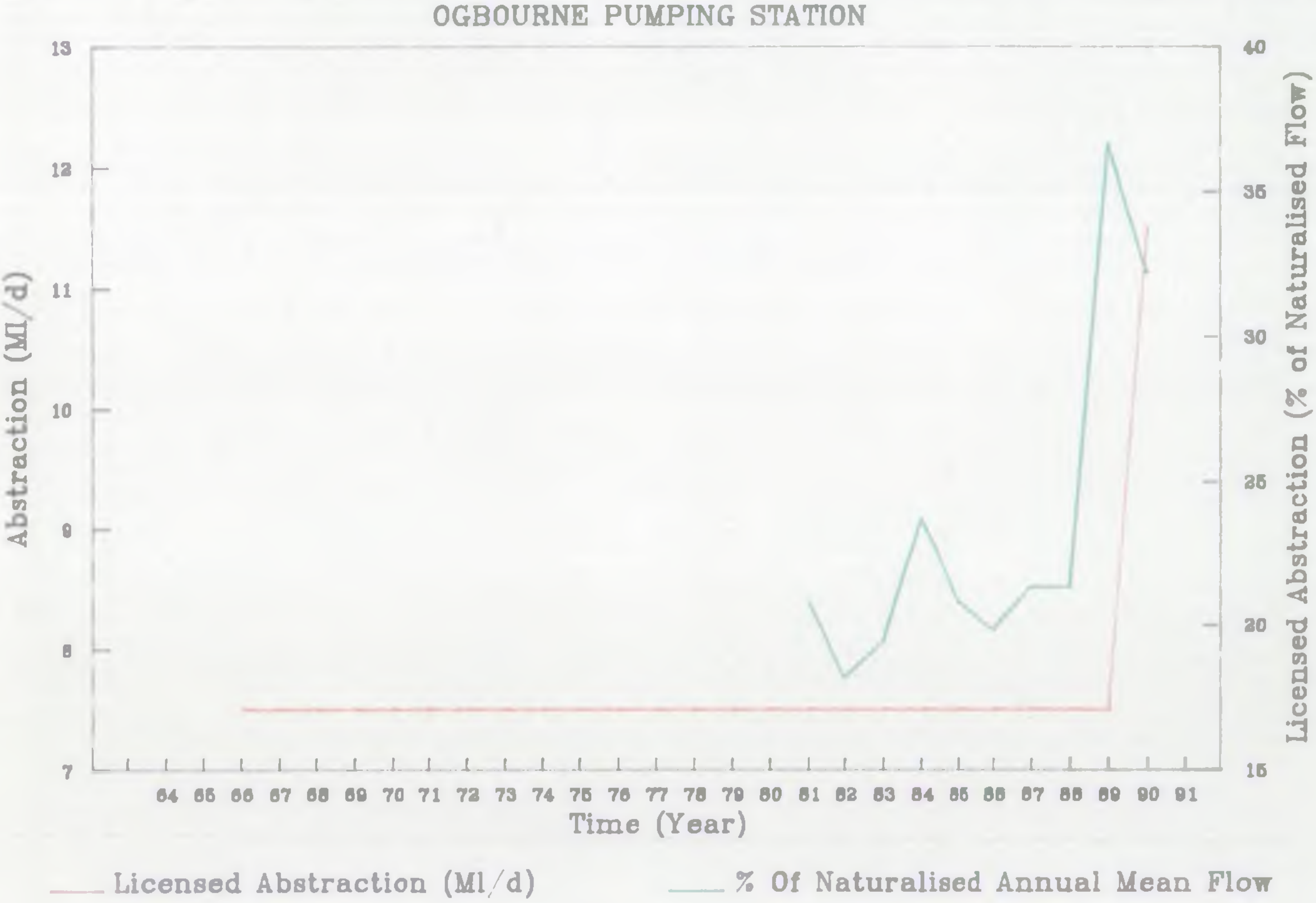
KNIGHTON PUMPING STATION



NETT LICENSED ABSTRACTIONS TO KNIGHTON EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.8

KENNET AND COLN RIVER LEVEL STUDY



TOTAL LICENSED ABSTRACTION FOR THE OGBOURNE SUB CATCHMENT EXPRESSED AS A PERCENTAGE OF NATURALISED FLOW

FIGURE 10.9

11. DISCHARGES

11.1 Sewage Works Discharges

The beneficial impact of the public supply discharges at Fyfield and Marlborough STW in reducing the impact of groundwater abstraction on surface flows has already been considered in Section 10. Public treated effluent discharges are, as discussed in Section 6, considered to provide the major contribution of both phosphate and ammonia to the catchment and a proportion of the BOD loadings. The in-stream concentrations of these parameters are all relatively low however and are considered unlikely to have any detrimental effect on the ecology of the catchment.

Both sewage treatment works pass comfortably their effluent discharge compliance standards.

11.2 Diffuse Inputs

The nitrate analyses in Section 6 show a steady increase in nitrate over the 30 year period of record. This is consistent with other agricultural catchments in the south east of England and is considered to be due to changes in land use from dairy to arable farming and consequent (i) application of nitrates and (ii) release of 'natural' nitrate from the soil following ploughing. The nitrate concentrations are not considered to be a cause for concern however.

A second diffuse input which had not been considered previously is decaying instream vegetation and leaf matter. It is reported that the number of trees overhanging and adjacent to the river has increased significantly over the post war period. Leaves are shed during the period of natural low flows and tend to build up in the river bed forming a silty organic mud. If the leaf and weed matter is not flushed out by higher flows in the Winter it can have a major detrimental effect on both weed growth and the breeding potential for wild trout during the following Spring.

11.3 Pollution Incidents

The change in agricultural land use from stock to arable farming is reported as being influential in reducing farm pollution incidents in the Kennet catchment (NRA pers. comm.).

Two significant pollution incidents have been reported, as described in Section 6. The most severe was the leakage of 5000 litres of diesel into the river in the late 1980's. This caused significant ecological damage at the time and was a contributory cause to the closure of a fish farm at Marlborough. However, there is no indication that any longer term damage was caused.

The second incident, in the reach above Marlborough, concerned the cutting of a trench across the river to lay a pipeline. This resulted in a major input to the river of suspended chalk sediment which made the river milky for a considerable distance downstream. This incident was noted as having a significant beneficial effect on the river in that the chalk solution acted upon the deposits of organic mud breaking down the organic material. The use of powdered chalk is an old river keepers' method of disseminating a build up of organic mud and is reported from the Hampshire Avon catchment in the 1960's (Sawyer, 1984).

12. RIVER MANAGEMENT

12.1 General

This section considers the impact on the river character of both the current river management practices and the many changes in river management which have taken place over the last 100 years. The issue of river management is important over the entire length of the Kennet from Swallowhead Springs to Knighton but the impact of changes to management appears to have been most pronounced in the upper reaches above Marlborough. The River Og and Aldbourne catchments were less intensively managed in the past and do not appear to have been influenced to the same degree.

The Upper Kennet has probably been used since pre-historic time for stock watering and as a source of fish. The first water mills are likely to have been constructed by the Romans. The period of intensive management of the river is considered to have started in the seventeenth century however with the construction of water meadows within the adjoining flat lying valley bottom.

In the 17th, 18th and 19th Centuries the river was a central part of the local economy and water flows were used to feed water meadows, drive watermills and sustain a good supply of trout. Fundamental to these purposes was the retention and use of all the water resources within the catchment. During this period there was also the available labour to control and manage the catchment much more intensively than is now possible.

The use of water meadows and water mills decreased significantly towards the end of the 19th Century but an increase in the interest in fishing for recreation ensured that the river continued to be closely managed. Following the First World War labour costs increased and, after the Second World War priorities within the river catchment changed from the principles of water level retention and management to those of drainage and flood alleviation.

12.2 Water Mills

Water mills require a reliable supply of flowing water to operate. If this supply is not available naturally, a method of storing water is used, either by a separate pond, or a depression or pool within the river which can be controlled by stops and hatches. The location of each of the mills shown on the map of Wiltshire of 1773 is indicated on Figure 12.1. The highest mill on the river, at Overton, was no longer marked on the earliest Ordnance Survey Map of 1817. The pools associated with the mills at Overton and Clatford were referred to by Colonel Maurice but appear to have been removed subsequently by dredging.

Both the Overton and Clatford mills would have operated by retaining stored water within the mill pools for intermittent release. The mills did not therefore require a continuous flow of water.

12.3 Water Meadows

Water meadows are constructed by digging parallel ditches within a low lying meadow, connected to the river by feeder channels and controlled by sluices. Releases of water were made into the meadows at regular intervals during the Winter, ideally such that a thin sheet of water passed over the entire meadow. This practise ensured that the ground temperature was kept above freezing and also introduced nutrients to the soil. The purpose was to encourage an early growth of grass for sheep during the later Winter and early Spring and so improve the numbers of stock which could over-winter. A hay crop was also taken in the Autumn.

Water meadows are believed to have been introduced to the Kennet catchment in the seventeenth century. The method was rapidly adopted along the length of the river and the location of meadows known within the reach above Marlborough are shown on Figure 12.1.

The holding up and control of water levels during the late Autumn and Winter period was clearly fundamental to the success of the water meadow system.

12.4 Fisheries and Weed Management

At first fisheries management would have merely consisted of netting the existing wild fish for food. Around the turn of the century however fish, and particularly trout, management became increasingly sophisticated. Full time river keepers were employed along the Kennet up to Clatford and a part-time keeper operated from Clatford to East Kennett. The sole purpose of the keeper at this time was to ensure a good stock of trout, often to the exclusion of the competing fauna (such as shrews, water voles, otters, herons, swans, ducks etc) which were treated largely as vermin.

Weed management was fundamental to this task and a healthy growth of submerged weed was considered essential as habitat both for the trout and its food chain. Runs were cut through the weed to ensure a good flow velocity was maintained and to aid the fly fisherman. It is recommended, in a fisheries management book written by a Kennet keeper, Lancelot Peart, in the 1930's, that weed be cut every morning during the growing season. Similar intensive and careful management was given to the silt and gravels. The silt was often removed by hand and the gravels were harrowed at the end of the year to ensure they were clean.

At present, the Crown Estate downstream of Marlborough is the highest reach with a full time river keeper and the manpower is no longer available for intensive river management.

The current problems regarding the loss of submerged weed in the Kennet catchment are discussed in Section 7 wherein it is stated that the fundamental control on growth is flow velocity. One of the effects of a healthy growth of weed however is that the flow velocity is reduced and river levels are thereby increased. An experiment has been carried out recently on the River Test using temporary weirs across a shallow weedless reach. Submerged weed *(Ranunculus)* started to develop along the bed downstream of the weir which was subject to an increased flow velocity. The weir was then removed and the weed itself acted as a natural weir, holding up flows and promoting further growth in the higher velocity wake downstream.

The loss of weed may have been a significant contributory cause to the general public's concern as to reduced river levels within the river. It has been reported (Aquatic Weed Research Institute, pers. comm) that major weed cuts may reduce levels within the river by over a half with no change in flow rate. Those reports are supported by use of Mannings equation, as used in flood studies. Values of roughness co-efficient for streams like the Kennet are considered to reduce by a factor of about three without a healthy weed growth, leading to a halving of river level compared to a weed-rich river.

12.5 Dredging

As reported above, the removal of silt was undertaken by river keepers as part of their duties, to ensure healthy weed and clean gravels. These activities did not disturb the hard packed nature of the gravel river bed nor the longitudinal sequence of pools and riffles, which are an essential feature of a natural chalk stream and provide a wide variety of habitat for both low and high flow velocity fauna and flora.

Reports and contemporary photographs from the 1930's and 1940's show widespread flooding in the Kennet catchment in this period (e.g. photos of flooding on Lockeridge High Street and the main road at Ramsbury in 1940).

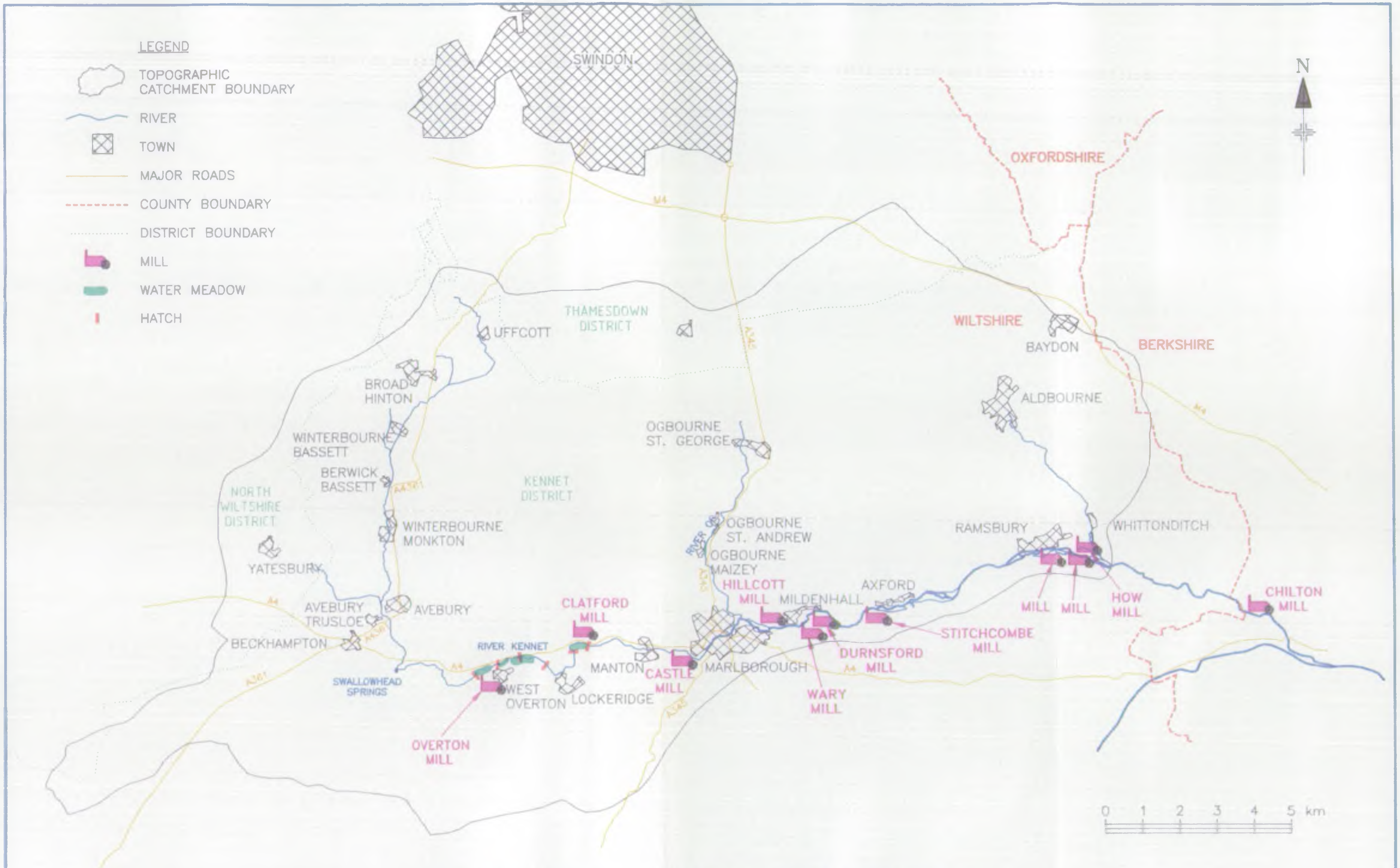
This may have been a regular occurrence in the preceding period (e.g. flooding at Fyfield, 1906) but it is also possible that the reduction in river management has led to some silting and weed clogging of the river section thus increasing the flooding risk. The management of the river on a commercial basis, particularly above Marlborough, had largely died out and the priorities of the Thames Conservancy were concerned more with reducing the risk of flooding in the catchment.

In the early 1950's, as a result of this concern, specific reaches of the river were dredged deeply and some were straightened. It is understood that a drag line was used in some at least of this work and the gravel base of the river was taken out and deposited on the sides to form gravel flood banks. Examples of this work include overdeepening along the Crown Estate reach downstream of Marlborough and through Axford, and river straightening around Lockeridge.

Further work in subsequent years has removed silt deposition but has not interfered significantly with the gravel bed.

One of the impacts of this work has been to improve considerably the flood protection afforded to the villages along the banks of the river. However, along those reaches that have been over-dredged the effect has been to lose the natural characteristics of a chalk stream. The flow velocity has reduced, with consequent increases in siltation, and the in-stream vegetation is more typical of a sluggish downstream river. Where these reaches are managed for fisheries this is largely on a 'put and take' basis as the conditions are not suitable for wild trout to breed.

Other reaches have not been so badly affected and river keepers and riparian owners have in some cases started to repair the damage by narrowing the river and/or backfilling. The option of undertaking further remedial works is considered within our Recommendations in Section 15.



UPPER RIVER KENNET CATCHMENT
RIVER MANAGEMENT : LOCATION PLAN

FIGURE 12.1

13. LAND MANAGEMENT

There have been a number of major long term changes in the land management within the Kennet catchment. In the nineteenth century there was a change from sheep rearing to arable development which reached a peak at the end of the century. In the early part of the twentieth century much of the upper Downs were returned to sheep and cattle or scrub land but, following the Second World War, the pendulum swung again in favour of arable farming, which received a further boost under the Common Agricultural Policy in the 1970's. In recent years changes in the provision of EC grants have encouraged a return to either livestock or set-aside.

These developments have seen great changes in the way that the catchment has been used. However, there is no evidence that these changes have had a significant affect on the river character beyond the increase in nitrate concentration reported in Section 11.

The change in transpiration pattern, between grassland and cereal cropping, and its impact upon recharge, was analysed for this reason using the Thames WA soil moisture model and the influence was found to be minimal (NRA, pers. comm).

The issue of plough pan development was considered, whereby repeated ploughing to the same depth produces a layer of very low permeability soil across the catchment, increasing runoff at the expense of recharge. However a local farmer reported (pers. comm) that the soils in this area were generally too thin for plough pan development and the plough tends to cut into the chalk. This is likely, if anything, to increase the recharge component.

The third issue considered was the impact of increased ploughing in promoting soil runoff and sediment build up in the river. There is an undeveloped corridor of scrub and meadow land retained around the river along virtually the entire reach of the Kennet downstream of Swallowhead Springs and this is considered to act as buffer to any increased soil runoff. Increased sediment may enter the river upstream of Swallowhead. There is no evidence from suspended solids data (Section 6) of any increase in sediment runoff. A build up of sediment has been reported in recent years but this is considered to be largely a result of decreased flow velocity leading to reduced flushing of the river bed.

One effect of changes in land management has been identified in the upper reaches of the River Og and Aldbourne however where the actual definition of the ephemeral stream channel is being muted by ploughing for arable development.

14. OVERALL SUMMARY AND CONCLUSIONS

14.1 Public Perceptions of Change

The existing state of the Upper Kennet catchment has been a cause of considerable public concern since early 1989. The overall concern has been with regard to (i) reduction in river levels and the overall size of the river and (ii) drying of the upper reaches above Marlborough. Drought is acknowledged as a contributory factor but the general belief is that groundwater abstraction for supply to Swindon and Devizes is a main, if not the major cause of this reduction in river size.

The public concern as to the impact of abstraction is not a recent phenomenon. Concerns were first expressed in the 1930's and were perhaps best formulated in the paper by Colonel Maurice in 1947. The comparison made by Colonel Maurice of the condition of the river in the 1940's with his memories of a much healthier river 30 to 50 years previously are, in many ways, echoed by the current comparisons between the present state of the river with that from the 1950's to early 1980's.

14.2 Changes Identified and Possible Causes

Above Swallowhead Springs

The reach of the Kennet above Swallowhead Springs is generally accepted to be naturally ephemeral in nature. The reach has never been managed apart from recent dredging for flood alleviation, and is little impacted by groundwater abstraction. It is considered that this reach remains in a largely 'natural' state and surface flows vary in response to changes in rainfall and groundwater storage.

Swallowhead Springs to Marlborough

Both the nature and the management history of this reach are rather complex. There are three major spring sources along the reach, at Swallowhead, Fyfield and Marlborough College, and there is historical evidence to suggest that, over the last 400 years or so, each has in turn represented the upstream perennial limit of the River Kennet. These changes are probably a reflection of long term meteorological variations.

The river appears to have dried to Marlborough Springs approximately once per decade since the 1920's and these dry periods correspond very closely with long term periods of reduced rainfall and effective rainfall.

The periods of dry river bed to Marlborough appear to be caused by either single years of extremely low Winter rainfall (1933/4 and 1975/6) or two to three year periods of reduced rainfall (1920-22, 1944-46 and 1989-92). The 3 year period to April 1991 represents one of the four severest long term droughts since 1920 for the Berkshire Downs and the most severe since 1946.

The impact of groundwater abstraction is considered insignificant along this reach. The mean surface flow to Marlborough is reduced in the order of 1 to 2 per cent by abstraction and low flows are reduced by approximately 5 per cent. The three boreholes operated by Wessex Water on the western boundary of the catchment are not considered to have any significant influence on the Kennet river flow.

The appearance of the river in times other than natural drought periods is considered to have changed considerably over the last century. The most significant changes occurred gradually between the mid to late nineteenth century and the end of the Second World War.

In the early-mid nineteenth century the reach above Marlborough was managed intensively for fishing, water meadows and mill operation. Central to this management was the requirement to control and retain the surface waters. This was done by an elaborate system of stops and hatches controlled by a skilled workforce. The same manpower was also employed in weed management and silt removal, undertaking both tasks largely by hand.

The river must have presented a very different appearance for much of the year to that seen currently with river levels held at a high level for occasional controlled releases. It is important to note that even during this period of intensive management it was still necessary to remove the trout each Autumn for storage at Ramsbury due to the seasonal low water levels.

In the years up to and following the First World War, the water meadows and mills fell into disuse and following the Second World War the manpower was no longer available to manage these reaches for fishing. As a consequence river levels were no longer maintained and the river returned to a more 'natural' state. On top of all these changes there was a significant drought period from 1944 to 1946. It was in the wake of all these impacts upon the upper reaches that Colonel Maurice wrote his obituary to the river.

In the 1950's the concerns of the Thames Conservancy in this reach were primarily with reducing the flood risk. There had been a major flood in 1940 which had submerged a large part of the Upper Kennet valley. Sections of the river were straightened and/or deepened and, in some cases the river was over-deepened by removal of the gravel bed. The impact of these measures was to both (i) change the nature of the affected stream section, removing the natural pool and riffle sequences and creating deep channels and (ii) increase the capacity of the river to conduct flows.

The current state of this reach is considered to be largely a natural reflection of the severe drought period. However, past dredging practices along some reaches have led to a change in river character away from that of an upland chalk stream.

Marlborough to Knighton Gauge

This is the present day upstream perennial reach of the River Kennet. The current (1989-92) drought period has reduced effective rainfall and thereby surface flow by approximately 35 per cent (see Section 9). Groundwater abstractions also have an impact on surface flows within this catchment. It has been estimated that actual nett groundwater abstraction has reduced natural flows by approximately 8 per cent. The impact of abstraction on low flows is estimated to be somewhat higher, as a reduction of 10 to 15 per cent on natural flow.

The impact of the drought on the flow regime is approximately four times as great as abstraction although abstraction is still a significant contributory cause of reduced flows along this reach. It should also be noted that if abstraction increased to the maximum under licence, it would lead to an estimated 15 per cent reduction in mean natural flow.

The most significant change along this reach in the past few years, however, has been the large scale loss of submerged weed and replacement with emergent and blanket weed. These changes in flora are considered to be largely a function of reduced flow velocity, particularly during the high growth season from February to May. Reduced flow velocity leads to an increased built-up of silt and mud which also has a detrimental affect on the submerged weed. Water quality is not considered to be a significant factor in this change.

One impact of weed loss is that water levels are reduced and this gives the appearance of a further reduction in flow rate. The loss of a healthy weed growth may halve the river level. On top of a reduction in flow rate of above

40 per cent due to drought and abstraction this will cause a severe impact in the appearance of the river. A secondary impact of weed loss is the loss of habitat for many of the fly larvae and crustaceans which form the base of the food chain for a natural chalk stream.

The loss of submerged weed on the same scale as on the Upper Kennet is reported from many of the other chalk streams of south east England. These catchments include those both affected and largely unaffected by abstraction.

The reduction in flow velocity is, along much of the reach, a product largely of reduced flow rate. However, a number of the lengths of river have been over-dredged in the 1950's, with consequent loss of bed gravels and a change in character towards that of a more sluggish lowlands river. As discussed above, over-dredging also encourages siltation and has a significant detrimental impact upon the natural chalk stream habitat.

The River Og

This river has not been managed significantly in the past and changes in catchment character are considered to be due to a combination of natural meteorological variation and groundwater abstraction. The impact of abstraction on the natural flow is less than, but of the same order as, the impact of the current drought. This indicates that, even in a non-drought year, the mean flow in the River Og is reduced to a natural drought year flow. There is also historical evidence, such as the old fish farm at Ogbourne Maizey and the use of the Og as a trout spawning tributary, that the flows in the River Og were both greater and extended further upstream in the past.

The Aldbourne

The Aldbourne appears to be a largely natural catchment reflecting natural meteorological variations.

14.3 Comparison of Study Findings with Public Perception

Swallowhead Springs to Marlborough

The two main periods of public concern identified with regard to the state of the river are the mid-late 1940's and the current (1989-92) period. At both times the focus of concern was the upper reaches of the Kennet above Marlborough and the underlying cause of the problem was considered to be abstraction.

This study has concluded that the main cause of the changes discussed in the 1940's was the major reduction in artificial water level controls over the previous half century combined with a fairly severe three year drought period. The changes in the character of this reach identified in the current period are largely a direct result of the current drought, with previous over-dredging as a likely contributory factor. The current drought is considered to be among the most severe on the 70 year record with regard to its effect on chalk baseflow. Groundwater abstraction appears to play no significant part in the changes identified in either period.

The public concern with groundwater abstraction in this reach is considered to be due to the following :

- The publicity received by other catchments, particularly in the south east of England, with respect to the impact of abstraction on the surface flow regime.

- The upstream perennial reach can vary by over 10 kilometres (from Swallowhead to Marlborough) between a drought and a high rainfall year. This unusual feature appears unnatural. However it is actually due to the discrete nature of the spring outflow, the low gradient along this reach and the large natural variation in groundwater level.

- The river dries to Marlborough approximately every 10 years. This is a sufficient period of time for it to be considered an unusual and unnatural phenomenon, particularly by relatively new inhabitants of the valley.

- There appears to be a widespread misconception that chalk groundwater abstraction leads to a cumulative depletion of groundwater resources and that, if abstraction continues, the situation is sure to become worse as aquifer levels are depleted. In reality, abstraction reduces aquifer levels but these levels rapidly re-stabilise at a lower level.

Marlborough to Knighton

The condition of the Kennet downstream of Marlborough does not engender the same degree of public concern as upstream. However, the state of this reach is of considerable concern to those who fish and manage the river. The major concerns are reduced river levels, loss of submerged weed and increased siltation. The validity of each of these concerns has been confirmed by the study and it is noted that similar issues are of concern in other catchments in the Region.

The primary reason for each of these problems, as discussed in Section 14.2 above, is reduced flow velocity. The major cause of reduced velocity is a reduction in the flow rate through the catchment although, in specific reaches, the problems have been greatly increased by over-dredging which enlarges the channel section area. It is accepted by the local fishing fraternity that the drought has had a major impact on the river but it is also considered that abstraction has increased the problems.

The Study found that drought is the major cause although abstraction is a significant contributory factor to reduced flow rates and is responsible for approximately 20 per cent of flow reduction. The main contributory factor to reduced river levels is weed loss however, the effect of which is probably as great if not greater than the impact of reduced flow.

15. SUGGESTED REMEDIAL MEASURES AND FURTHER STUDIES

1. There is a large amount of remedial work already taking place within the study area, particularly along the Crown Estate downstream of Marlborough, and largely in the form of small scale river engineering. The river has been narrowed and sarsen stones have been added in an attempt to increase flow velocity. The hatches, which are all of the underflow type, have been opened and temporary weirs have been constructed in an attempt to encourage weed growth. Chalk seeding has been experimented with to try and break down the dark organic muds which now cover much of the gravel. These experiments have had some success in improving the river condition but at present are on a limited scale.

   An overdredged section is also being backfilled at Chilton Foliat on the Kennet downstream of the Study area. The river bed is being restored by backfilling with gravels and plans are also being considered for subsequent reinstatement of the disused water meadow system.

   It is recommended that the impact of these and any other works on the condition of the river should be monitored closely and, if necessary, further remedial works should be funded. The Crown Estate reach downstream of Marlborough could be considered as a trial reach to assess the effect of various flow velocity enhancing measures prior to recommending them elsewhere in the Thames Region.

2. Certain reaches have been badly damaged by over-dredging and straightening. The main remedial options are (i) backfilling and restoration of the existing river length or (ii) cutting a new river section in the adjacent flood plain, ensuring a 'natural' meander, pool and riffle sequence and cross section. It may be appropriate to identify the practical considerations and concerns of these options within an outline Feasibility Study.

3. The loss of submerged weed and replacement with blanket weed and algae is a serious problem, which has been reported from many other catchments. It is recommended that a more detailed Study is carried out, on a regional or national basis, to establish the causes and to identify possible remedial measures.

4. Actual abstractions have a measurable impact on the surface flows to Knighton gauge. This impact would be doubled if the abstraction under licence were maximised. The impact of abstraction to licensed maximum on specific reaches could be considered in more detail. It is recommended specifically

that the impact of Axford source is investigated further with a view to formulating NRA policy on the licence prior to the licence review in 1994.

5. The relative contributions of baseflow losses and groundwater storage to groundwater abstraction during a low flow period is not well understood. It may be appropriate to investigate these interactions further, particularly in relation to the Axford Source, as per 4 above. Use and development of the existing groundwater model for the River Kennet may be appropriate in this context.

6. A public document is recommended which would summarise, in say 4 to 5 pages, the main findings of the Study.

7. The findings of the BHS (British Hydrological Society) Study into the impact of droughts on aquifer resources should be considered with regard to this Report and the findings reviewed as appropriate. The Report is due for publication later in 1992.

8. The flows in the River Og are considered to be reduced significantly due to abstraction. The impact on the in-stream ecology is not known however. It may be appropriate to investigate this sub-catchment further and consider for example, the impact of abstraction on (i) Summer flows and (ii) in-stream ecology.

9. The issue of Drought Orders, particularly for (i) additional abstraction from the River Og and (ii) reducing the prescribed flow controlling Axford should be considered carefully in relation to these Study findings.

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APPENDIX A
TERMS OF REFERENCE

Upper Kennet and Coln River Level Study

Terms of Reference

Introduction

In recent years concern has been expressed about low levels and the generally poor condition of a number of "headwater" rivers of high environmental value in the Thames catchment. Individuals and organisations outside the NRA and internal departments have raised the issue. There is a fear that certain rivers are "dying", although measurements of river flow and groundwater level do not indicate any trends that would not have been expected given the dry weather experienced during this period.

Following extensive publicity, many people have heard of the alleviation of low flow ("ALF") cases, where heavy abstraction is acknowledged to have caused low flows. In the catchments which are to be studied, abstraction occurs but is relatively light. However, there is a perception that abstraction is one of the causes of low levels and poor condition and there is a call for these rivers to be added to those whose flows are to be improved. Consequently, it is essential for the NRA to establish as objectively as possible, what changes, if any, have occurred and what the causes have been, before making commitments on policy and expenditure.

Objectives

The objectives of the study are:-

(i) To investigate the perception that the levels, flow and character of the named rivers have changed within living memory and that the water levels in the aquifers have declined.

(ii) To provide the evidence that such changes have occurred.

(iii) To determine the extent of the changes.

(iv) To assess the possible causes of the changes.

(v) To indicate in outline possible remedial measures.

(vi) To recommend any further studies and monitoring.

The Study Rivers

(i) The Upper Kennet - from the source near Uffcott (SU118786) to the flow gauging station at Knighton (Ramsbury SU294710) including the tributaries of the Og and Aldbourne.

(ii) The Coln - from the source at Brockhampton (SP035234) to the recently commissioned flow gauging station at Fairford (SP151012).

The Problem

Local residents and other people who use the river, such as fishermen, have complained of low river levels and flows and the poor condition of the river. The poor condition of the river is said to include silting up of the channel, poor weed growth of useful species such as rananculus, but growth of blanket weed and undesirable species such as starwort, reduced fish populations and changes of colour to a milky green hue.

Sources of Information

Information available from NRA - Thames Region.

Continuous flow records of various durations are available at several locations for both rivers.

Additionally spot flow measurements are available from a range of locations and the source of the Kennet has been observed approximately monthly since 1972.

Areal values of rainfall, evapotranspiration and percolation (derived from a soil moisture model) are available on a daily, monthly or annual basis.

Groundwater level records of various durations and frequencies are available at many sites.

Groundwater contour maps have been produced.

Records are available of the locations of all licensed abstractions. For the major abstractions records are available of the monthly quantities taken from the late 1960's. In both catchments there are many agricultural licences for which the NRA receive no returns. One abstraction which may influence the Kennet lies in NRA-Wessex Region, data should be sought from them. It should be noted that the actual quantities abstracted by individual licence holders is confidential information. The consultant should not disclose or publish this information to anyone outside the NRA without the permission of the licence holder. The consultant should be aware that the final report will be seen by members of the general public.

A fisheries report for each river has been produced, and fisheries officers have much local knowledge.

River biology data are available from at least 1977.

River water quality data (oxygen levels, BOD, suspended solids, ammonia) are available from approximately 1972.

The Environmental Quality district offices have information on pollution incidents etc. This will be made available. Information on the Upper Kennet is held at Fobney, Reading, that for the Coln at Oxford.

A river corridor survey of the Kennet was carried out in 1987, and a short section of the Coln is due to be surveyed before commencment of this study. The conservation section have also had some correspondence concerning the study rivers. This will be made available.

There has been considerable correspondence between NRA staff and interested members of the public. This will be made available.

Information External to NRA

The consultant should explore all sources of information which they consider relevant. These should include - archive material such as photographs, postcards, newspapers etc; private fishery records, and information held by riparian owners, river bailiffs, local authorities and organised groups such as Action for the River Kennet and Kennet Valley Fisheries Association.

Thames Water Utilities should have information on the development of the sewage system, and effluent discharges.

Scope of The Study

The study will be divided into two stages:-

Stage I
In this stage the consultant will be required to:-

(i) Review and present all relevant information concerning river and groundwater levels and the condition of the two rivers over the past 30 years.

(ii) Assess whether there has been any change in river levels or condition, and report on the amount of change.

(iii) Report on the differences between the surface and groundwater catchments.

Stage II
In this stage the consultant will

(i) Investigate the causes of any changes which should include:-

- hydrological factors eg. rainfall
- river maintenance eg. structures, weed clearance, channel clearance.
- operational structures eg. sluices, diversions.
- agricultural practices eg. field drainage, fertilizers.
- abstractions and effluent returns.
- wildfowl populations.
- any other factors considered relevant by the consultant.

(ii) Provide a quick assessment of possible remedial measures to restore the river levels and quality, and groundwater levels.

(iii) Provide recommendations for further monitoring or future studies.

Administration

Programme
The study is required to be completed to the point of submission of the draft Final Report within 4 months from the date of engagement and the Final Report 1 month later.

Reports
The following reports will be required from the consultant:-

(i) An outline report summarising the findings of the Stage I work, at a date to be agreed before the commencement of the contract. 5 copies.

(ii) A draft Final Report together with any appendices which shall be provided within 4 months from the date of engagement. 20 copies.

(iii) Brief written Progress Reports circulated at least one week prior to any progress meetings.

Progress Meetings will be arranged as required.

Other Matters

Public Relations
An important factor in the Authority's decision to proceed with this study is public concern about the condition of the rivers covered by the study. As a result there has been considerable contact between the Authority's staff and the public through correspondence and meetings with individuals and groups of people.

It is envisaged that the consultant will have discussion with interested parties. The consultant may wish to make site visits which will involve contact with the public. In relation to these activities, which will normally be carried out independently of Thames Region's staff, the consultant is asked to note that the Region is striving to achieve good relations with the public, and to demonstrate its responsibility for the environment.

It must, however, be appreciated that if an undesirable condition is identified there is no automatic decision to deal with it. Such a decision may follow completion of this study, but no undertakings can be given to interested parties at the present time.

Entry onto Private Land
When not accompanied by NRA staff, the consultant will be expected to make his own arrangements for entry onto private land. In both making arrangements and entering onto the land the Consultant should bear in mind the NRA's wish to maintain good public relations and should contact the Authority in the event of difficulties.

CMG
22/7/91
/LJ

APPENDIX B
TECHNICAL APPENDIX

APPENDIX B - FLORAL AND FAUNAL SPECIES ASSOCIATED WITH UPSTREAM REACHES OF CHALK STREAMS

Plant species typical of the upstream retches with faster flows over gravel substrates are the water crowfoots *(Ranunculus spp)*, starworts *(Callitriche spp)* and water cress *(Nasturtium officionale)*. *Ranunculus calcareus* often dominates the river bed in the faster currents while *Nasturtium* forms beds of siltier substrates in areas of lower flow. These two species may show a cyclical succession where *Nasturtium* starts to colonise *Ranunculus* beds that have raised their levels and lowered the flow by accumulating silt over the summer months. Higher winter flows wash away these weak-rooted associations and the cycle repeats with the re-establishment of the *Ranunculus* beds (Dawson, Castellano and Ladle 1978).

With slower flows over finer substrates *Ranunculus* tends to be absent and other submerged species such as mare's tail *(Hippurus vulgaris)*, opposite-leaved pondweed *(Groenlandia densa)*, river dropwort *(Denanthe fluviatile)* and Canadian pondweed *(Elodea canadensis)* may colonise. The relative constancy of the water levels favours the development of a rich marginal fringe of emergent aquatic plants including taller reed species, common reed *(Phragmites australis)* reed sweet-grass *(Glyceria maxima)*, branched burr-reed *(Spargarium erectum)*, yellow flag *(Iris pseudocoris* the sedges *Carex acutiformis, C.riparia and C. paniculata* and lower emergents such as water mint *(Mentha aquatica)*, brooklime *(Veronica beccabunga)*, water forget-me-not *(Myosotis scorpioides)* lesser water parsnip *(Berula erecta)* and fools water-cress *(Apium nodiflorum)*.

There is typically a high diversity of aquatic invertebrates and the larval forms of mayflies *(Ephemeroptera)*, caddisflies *(Trichoptera)* true flies *(Diptera)*. In particular black flies *(Simuliidae)* and midges *(Chironomidae)* are numerous in addition to the permanent underwater inhabitants, species of molluscs, freshwater shrimps, worms, leeches and flatworms.

Many animals of the faster flowing reaches are specialised for filter feeding or grazing on algal films. They are often streamlined and may have other adaptations such as the holdfasts of *Simuliid larvae* or exploit microhabitats of reduced flow between the stems of *Ranunculus* or the gravel interstices. These animals are usually dependent on high oxygen levels in the water. The presence of *Ranunculus* beds greatly increases the biomass of invertebrates compared to a bare gravel substrate, not only because it offers physical living spaces but also because of its high photosynthetic rate and the evolution of much oxygen into the water (Giles, Phillips & Barnard 1991, quoting Witcombe).

Species typical of fast-flowing, base-rich waters include mayflies of the families *Ephemerellidae and Baetidae* the caddis families, *Lepidostomatidae, Ryacophilidae, Goeridae, Glossosomatidae, Polycentropidae and Hydropsychidae*, the river Limpet *Ancylus fluviatilis*, the *Elmidae* (riffle beetles) and *Simuliidae* (blackflies).

Pools of slow moving or still water in the river channel, where silt and organic matter accumulate, select for a different community of invertebrates. Many feed on organic detritus or are active predators (e.g. water boatmen, dragonfly larvae). The principal families in such habitats are the *Gerridae and Corixidae* (water boatmen) *Dytiscidae and Hydrophilidae* (diving beetles), the Mollusca e.g. pond snails, ramshorn snails *(Lymnaeidae and Planorbidae)*, oligochaete worms and the *Asellidae* (the water hog louse). Certain mayflies and caddisflies may be present particularly those of the *Ephemeridae and Leptophlebidae* respectively. In the natural river system with a sequence of riffle and pool formations both flowing and still water communities will be represented giving a very high, overall diversity.